ANALYSES OF FREQUENCY MODULATED SCREENING ON NEWSPRINT

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Abstract: The fineness of an amplitude modulated (AM) screen is described by the screen rulings in lines per inch while a frequency modulated (FM) screen is measured by the microdot size in µm. The relationship between the microdot size in FM screen and the screen ruling in the AM halftone is implicit and not clear. This research uses the concept of the total border length per unit area on film as a common parameter to characterize both FM and AM screens on newsprint. By comparing the border length between FM screens to a reference AM screen, this study discovered that the border length of dots on film relates to the dot gain on press sheet. Thus, we are able to predict and compensate for the dot gain between AM and FM screens among the screens tested. In addition, by varying solid ink densities on a keyless newspaper press, we found that there is no significant color variation between a 42 µm FM screening and that of a 85 lpi AM screening.

Introduction

Due to the limitation of the spatial resolution of human visual system, halftone patterns become an effective mechanism to render gray scale information. Similar to the AM and FM radio waves, for AM halftone the dot frequency is constant and dot size is amplitude modulated; for FM halftone the dot frequency varies and dot size is constant. An AM screen is specified by its screen ruling, i.e., lines per inch (lpi), and an FM screen is specified by the size of micro dots which is usually given in microns (µm, or 10^{-6} m).

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Frequency Modulated (FM) screening has been praised for its apparent resolution advantage over conventional halftone screening. Studies showed FM screening can be processed with the existing technology, and bring about a visible improvement in image quality on newsprint. This study focused on the FM halftoning pertaining to newsprint.

Research Questions

A color reproduction system is typically calibrated for a given screen, paper, ink, and press conditions. In our 1995 TAGA paper, "Press Performance Comparison between AM and FM Screening," we discussed how to compensate for dot gain differences between AM and FM screening. In this paper, we wish to explore if there is a commonality between AM and FM screening. A common characteristics of both types of screen is the border length of halftone dots per unit area. The other common parameter of both types of screen is dot gain.

There are two objectives in this study. The first objective focuses on if there is a correlation between the border length of FM halftones to a reference 85-lpi AM halftone and the corresponding dot gain between the FM halftones and the reference 85-lpi AM halftone.

Previous studies indicating that FM screening has more latitude in solid ink variation than AM screening during printing. The second objective focuses on if this is the case between the 42µm FM screened image and the 85 lpi AM screened image when solid ink densities of the press run on newsprint are varied.

The Specifications for Non-Heat Advertising Printing (SNAP) recommends 85-lpi AM screen for newsprint. UGRA recommends 42µm FM halftone for newspaper printing. Therefore, in this study the 85-lpi AM screen was used as the reference; and the 42µm FM screen (UGRA Velvet screen) was used for the press stability part of the test.

Experimental Procedures and Data Collection

Border length and dot gain measurement

To search for the relationship between border length and dot gain for both AM and FM screening, the border length ratio of different spot size FM screens to a reference 85-lpi AM screen and the maximum dot gain difference between them were collected and analyzed. All border length measurements were made on film. The film was output using AGFA SelectSet 5000 imagesetter. Dot gain was derived from density measurement on press sheet with the Murray-Davies formula. The following offers further details.

1. Border length on film

The steps of scales of AM and FM screened films were captured using a video microscope and analyzed using Imagelab™ Image Analyzing software. The software captured the CCD video image into a 512 x 464 pixels image (see figure 1). The total border length was calculated by the number of pixels along the borders of all dots within the captured image.

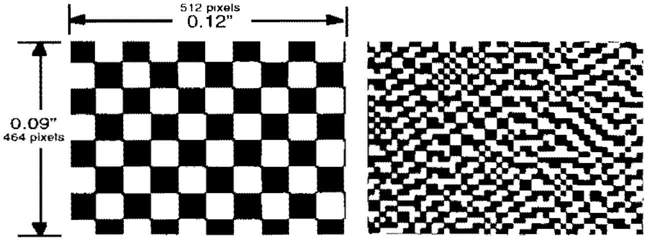

Figure 1. The enlarged AM (left) and FM (right) images captured by the CCD video at 50 % film dot area.

2. Dot gain measurement on press sheet

The press sheet samples were collected at SNAP printing conditions (see appendix A). An X-Rite 418 densitometer was used for the density measurements of the press sheet. The spectral response is status-T and the geometry of instrument is 0/45 as defined in the ANSI CGATS.4 document. The dot gain was calculated using the Murray-Davies equation.

<u>Color variation of FM and AM screens due to inking change</u>

The second objective focuses on if there is a significant difference between the 42μm FM screened image and the 85 lpi AM screened image when solid ink densities of the press run on newsprint are varied. There are three important considerations in carrying out the experimental procedures: (1) FM images must be compensated for dot gain so that AM and FM reproduction have similar appearance; (2) the inking on press must be uniform for both AM and FM images; and (3) a wide range of inking variations are tested. To do so, the experimental procedures are further explained below.

1. FM dot gain compensation in prepress

All pictorial images were prepared as AM halftones using the KEPS PCS100 Color Management System. This system contains a newsprint device color profile that is used by the newspaper industry to produce quality images for newsprint.[1] To match the tone reproduction between AM and FM halftones, the transfer curve was applied to the FM screened images to compensate for dot gain. This transfer curve was derived by using the Jones diagram technique from a previous newspaper press run.[2]

2. Uniform inking between AM and FM reproduction

Uniform inking between AM and FM images can best be assured through layout and imposition of the test form. Instead of placing the IT8.7/3 color block side by side, it was placed in line with each other on the press sheet. The positive-feed keyless feature of the Newsliner newspaper offset press further assures the inking uniformity requirement.

3. Determining inking variations

In order to observe possible color differences due to inking changes, a wide inking variation was necessary. Typical density variations which are acceptable, according to SNAP, is $\pm$ 0.05. In this experiment, the range of density variation was set at $\pm$ 0.20.

There were five levels of inking in this experiment, i.e., two inking levels lower and two inking levels higher than the normal inking condition. The normal inking condition was set to conform to SNAP specifications. Table 1 shows the target densities of the five inking levels.

SID	C	M	Y	K
Low 1	0.73	0.73	0.68	0.88
Low 2	0.83	0.83	0.78	0.98
SNAP	0.93	0.93	0.88	1.08
High 1	1.03	1.03	0.98	1.18
High 2	1.13	1.13	1.08	1.28

Table 1. Target density values of five inking levels.

4. Sample collection

After the press has reached to its equilibrium for each inking level, press sheet samples were collected at every thirty seconds. Twenty samples were collected within ten minutes at each inking level. To assess the average colorimetric values at each inking level, only five samples, labeled as #1, #5, #10, #15, and #20, were measured.

5. Color measurement

The IT8.7/3 basic color set target containing 182 color patches in the press sheet was measured with an X-Rite 938 Spectrodensitometer. The 85-lpi AM and compensated 42µm FM screened targets were measured at all samples. Colorimetric data (D50 illuminant and 2 degree observer) which conform ANSI CGATS.5 were collected.

6. Data analysis

To assess color differences due to inking change, colorimetric values of the AM IT8.7/3 targets at normal inking were used as the reference for calculating the AM screen's color variations between inking levels. Similarly, the FM IT8.7/3 targets at normal inking were used as the reference for calculating the FM screen's color variations between inking levels. The final color difference was the average of the color difference of 182 color patches expressed in ΔE.

Results and Discussion

Press run assessment

Table 2 shows the target densities and the average solid ink density of 20 samples at each inking level. This table verifies if the press run conforms to the target densities. It was observed that discrepancies between the target density and the measured density are small, i.e., less than 0.05 with the exception of high inking levels (shown in Italized type). The density differences between the target and the high inking level were mainly caused by density dry back and the press inking control limits.

SID		C	M	Y	K
Low 1	Target	0.73	0.73	0.68	0.88
	Average	0.71	0.71	0.67	0.87
Low 2	Target	0.83	0.83	0.78	0.98
	Average	0.83	0.82	0.74	0.96
SNAP	Target	0.93	0.93	0.88	1.08
	Average	0.9	0.89	0.82	1.06
High 1	Target	1.03	1.03	0.98	1.18
	Average	0.98	0.98	*0.91*	1.18
High 2	Target	1.13	1.13	1.08	1.28
	Average	*1.07*	*1.05*	*0.97*	*1.17*

Table 2. Target densities and the average solid ink density of 20 samples at each inking level.

Border length vs. dot gain

Figure 2 shows the relationship between border length and its corresponding % film dot area. It suggests that (a) there is symmetry at the 50% dot area, i.e., the maximum border length occurs at the 50%, (b) FM screening have longer border length than the AM screens tested; and (c) the smaller the microdot, the longer its border length is.

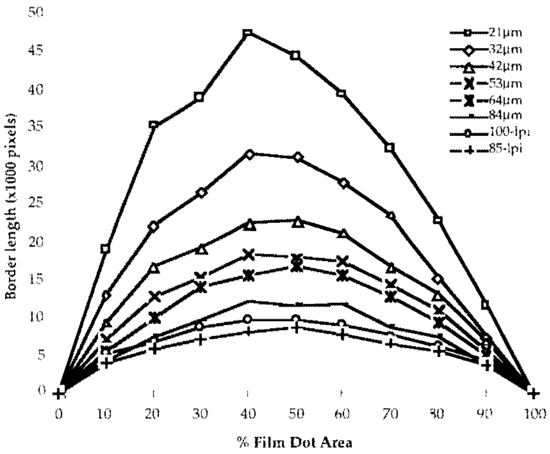

Figure 2. Border length vs. % film dot area.

Figure 3 shows the relationship between % dot gain of the cyan printer and its corresponding % film dot area. The major difference from Figure 2 is that there is no symmetry, and the maximum dot gain shifts from 50% FDA to 30% FDA as the FM microdot becomes smaller.

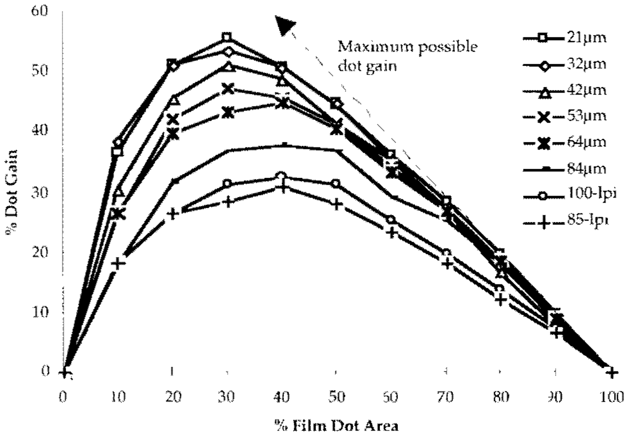

Figure 3. Cyan dot gain vs. % film dot area.

Notice that we are able to describe the border length vs. film dot area relationship in Figure 2, and the dot gain vs. film dot area relationship in Figure 3. With the use of the 4-quadrant Jones diagram, we can derive the relationship between border length and dot gain (Figure 4). As shown in the lower left quadrant of the diagram, the border length vs. dot gain relationship is a loop, i.e., for each given border length as input, there are two dot gain as output with the exception of the maximum.

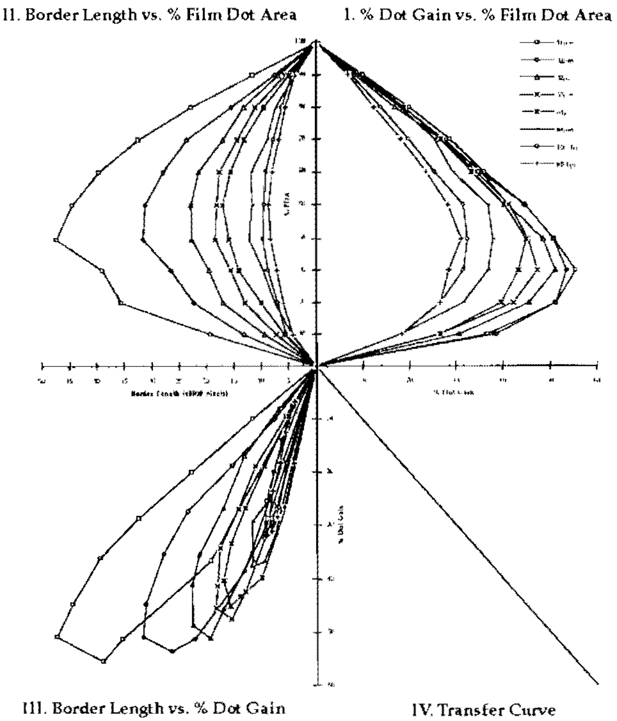

Figure 4. Border length vs. Dot gain.

If we are going to describe the relationship of two halftone screens by the border length, it is desirable that we describe the relationship by its maximum border length ratio. This is also true for describing the dot gain difference of two screens at its maximum dot gain point. In other words, the maximum dot gain difference can be determined by mapping the maximum border length from Figure 4. And the maximum border length ratio can also be derived by mapping the maximum dot gain also from Figure 4.

Two sets of data were generated from the experimental data. The first data set was derived from the maximum border length ratio between various screening conditions. The second data set was derived from the maximum dot gain difference. Both sets of data relate AM and FM screening together by means of border length ratio (figure 5). Statistical analysis was performed to determine whether the two sets of data were the same. The results show that there is no significant difference between the two sets of data. In other words, we can use the curve in Figure 5 to predict the maximum dot gain difference from the maximum border length ratio on film between a FM screen and the 85 lpi AM screen.

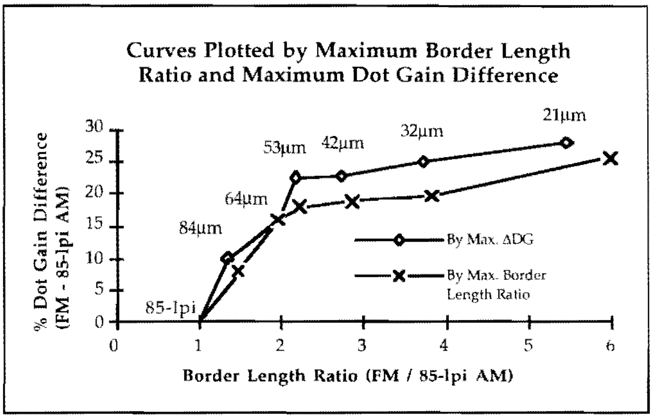

Figure 5. The graph of the maximum border length ratio and the maximum dot gain difference.

To summarize, the experimental finding and statistical analysis suggest that (1) the higher the border length ratio, the higher the dot gain of the screen in question relative to a reference screen; (2) high dot gain difference occurs at border length ratios of 2.5 or less, the rate of dot gain difference change reduces when the border length ratio is greater than 3.0; and (3) the maximum border length ratio for a given screen is where the maximum dot gain difference occurs.

Changes in Solid Ink Density vs. Color Variation

Color variations due to inking change were analyzed by comparing colorimetric differences in ΔE of a given inking to its normal inking. For the AM inking series, the 85-lpi IT8.7/3 target printed at the normal inking condition was its reference point. For the FM inking series, the 42µm compensated FM IT8.7/3 target printed at the normal inking condition was its reference point. Table 4 shows the color variations of the 85-lpi AM screening and the 42µm FM screening under different inking levels.

ΔE	AM (85 lpi)	FM (42 µm)
Low 1	7.88	8.29
Low 2	3.3	3.4
SNAP	0	0
High 1	3.17	2.93
High 2	6.12	5.51

Table 4. Color variation of FM and AM screening under different inking levels relative to its normal inking.

Figure 6 is a graphic depiction of the colorimetric variation of FM and AM screens due to the inking variations. By observation, we can see that (1) the magnitude of ΔE variation is proportional to the inking change, and (2) the closeness of the two lines indicates that the compensated 42μm FM has the same color variation (ΔE) as 85-lpi AM in both increased and decreased inking levels. In all cases, the color variation differences between 42μm FM and 85-lpi AM halftones over a wide range of inking variation is less than 1ΔE which is not noticeable.

Based on the above finding, this research concludes that there is no significant variation between FM and AM screening when solid ink densities of the newspaper press are increased or decreased.

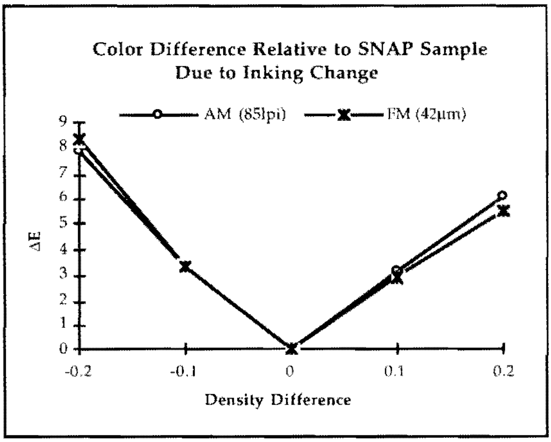

Figure 6. Color variations of FM and AM screens under five inking levels.

Summary and Conclusion

The first part of the experiment investigated if there is a relationship between the maximum border length ratio of FM screens to a reference AM screen and the maximum dot gain difference between them. The results show that the higher the border length, the higher the dot gain of the screen in question. In addition, the maximum border length ratio for a given screen is where the maximum dot gain difference occurs.

The second part of the experiment investigated if there is significant color variation between FM and AM screening when solid ink densities are varied. The results show that there is no significant color variation between AM and FM screening over a wide range of solid ink density variation. The above finding is not in agreement with previous studies indicating that FM screens have higher latitude to the inking variation. A possible explanation to the discrepancy is that newsprint was used in this experiment instead of coated paper.

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References

1. Kodak Electronic Printing Systems, "PCS100 Software User's Guide," Version 2.0, 1994.

2. Robert Y. Chung and Li-Yi Ma, "Press Performance Comparison between AM and FM Screening," TAGA Proceeding, 1995.

Appendix A.

Equipment and materials used and the press run specifications.

Prepress:

Computer:	PCS100 Image Station (Quadra 950)
Monitor:	Apple 21" (P22 phosphor set)
Device Profile:	Newsprint Litho AD (260 TAC, 30% GCR)
Screen:	AM – 85-lpi AGFA Balanced Screen FM – 42µm UGRA Velvet Screen
Software:	QuarkXpress 3.31, Photoshop 2.5.1, UGRA Velvet Screen v. 1.5
Imagesetter:	AGFA SelectSet 5000
Film:	AGFA Alliance Recording HN

Press:

Press:	Goss Newsliner
Paper:	Weyerhaeuser Lightweight Domestic, 27.7 g/m^2, 28" width
Plate:	3M Viking
Plate Exposure:	Solid step 3 at UGRA wedge
Ink:	Black–Flint low rub oil base Color–U.S. Soy Ad Litho ink
Ink-down Sequence:	CMYK
Printing Speed:	30,000 impression per hour
Printing Specifications:	Specifications For Non-Heat Advertising Printing (SNAP)