Max-imize Your Color: July-2011
Expert Tips from our Color Scientist Max Derhak

Controlling Output Quality Using Advanced Variable Dot Controls with Automated Ink Restrictions in X10

Advanced Whitepaper

With the release of the Version X10 RIP software from Onyx Graphics, profiling media has become much simpler. Key to this improvement is the new automated ink restriction tools in Media Manager. Usually, the default settings are adequate for getting reasonably good results. However, when profiling print modes that utilize variable dot technology (either through variable drop sizes or selective striking of dots), adjustments to variable dot usage are possible as part of printing the ink restriction swatch. With this advanced tool you can account for print artifacts and help to improve output quality.

This document explains how to modify variable dot settings for a single channel, with an example of using a variable dot configuration to account for print banding.

Advanced Variable Dot Control in Media Manager

When profiling with Automated Ink Restrictions, the variable dot settings are accessed by pressing the "Variable Dot Setup…" button in the Ink Restriction print swatch dialog (See Figure 1). (Note: Changes made to the variable dot settings require the ink restriction swatch to be re-printed and re-measured which will potentially invalidate any other steps of profiling for the print mode that have already been completed).

This tool will allow you to independently control the variable dot usage for each ink channel available in the printer as well as import and export curve settings for similarly defined print modes.

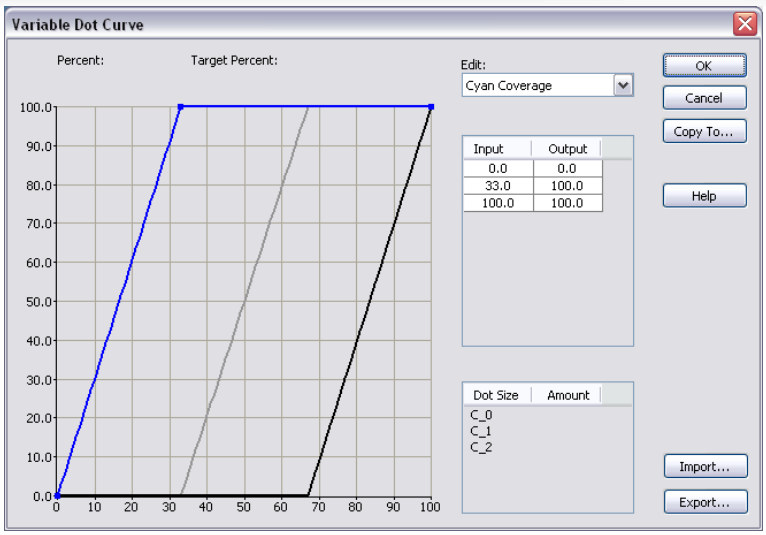


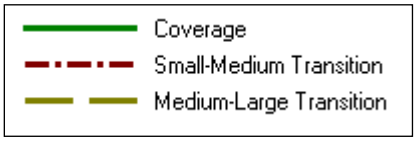
Figure 1 – Variable Dot Setup Dialog

This dialog displays variable dot curves for an ink channel as an ink coverage curve (blue) as well as curves (grey & black) that control the transitions between the available drop sizes. In this instance (and the examples used in this document) the print mode has three drop sizes available which means that there are two ink transition curves. Variable dot settings are controlled by a single ink channel at a time.

Once changes to the curves have been made for one channel, they can be copied to other channels available in the print mode. Note: Other printers may support more drop sizes, but the techniques still apply. It is useful to use the display of the amounts of the dot sizes implied by the curves as the cursor is moved over the curves while editing and making changes.

Default Variable Dot Curves

Each printer driver defines default curves associated with the ink configuration used by the print mode. For many printers, the default curves will be the same as those shown in Figure 1. The curves in Figure 1 are also shown in Figure 2 with a simulated example that represents the variable dot output associated with the curves.



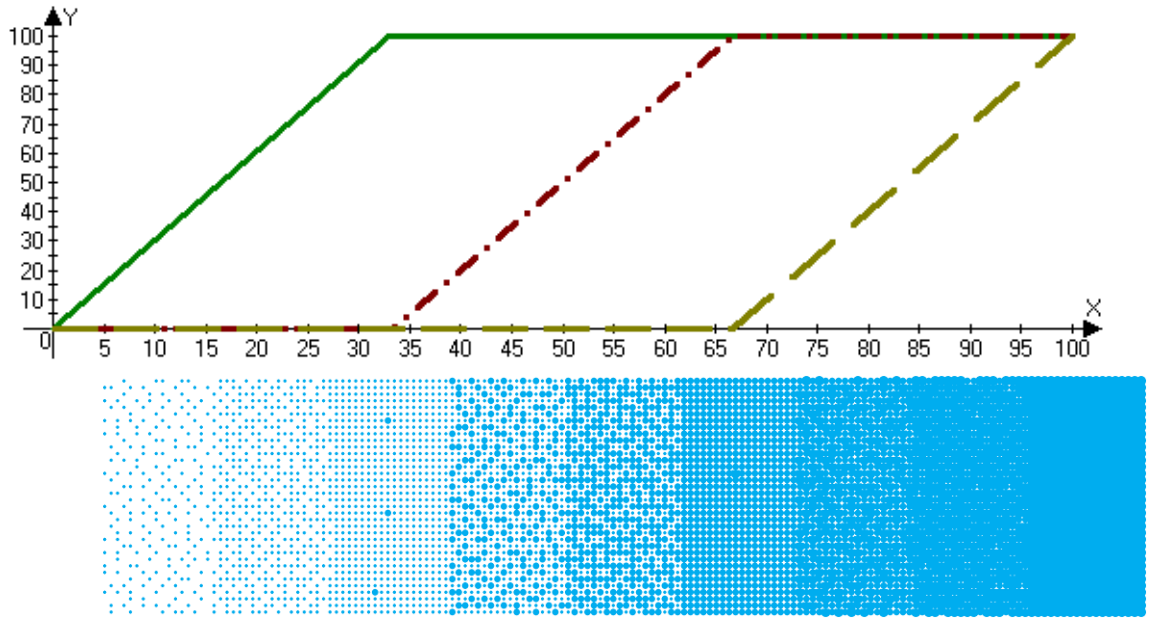


Figure 2 – Default Variable Dot Curves with the Simulated Output

To better understand the effect of changes to the Variable Dot Settings on the output, the remaining discussion will present various configurations of both coverage and transition curves along with simulations of the output that each set of curves produces.

What do the curves control?

The coverage curve controls the number of dots placed regardless of the type of dot placed. The horizontal direction on the graph corresponds to desired ink use. The vertical value of the curve defines the actual coverage of dots used.

In Figure 2 the coverage curve goes from point (0,0) to (33, 100) and then to point (100, 100). This can be seen looking from left to right in the simulated output as the dot coverage increases until 33% at which point 100% coverage of dots is achieved. The remaining patches in the output are made up of a solid fill of dots that change in size from small to large.

The transition curves define the **relative** mixture of dots that are actually placed. At each horizontal location in the chart, the relative positions of the transition curves determine the relative amounts of each dot size for the desired ink coverage.

Regarding the output in Figure 2, because the Small-Medium transition curve goes from (33, 0) to (66, 100) the dots go from 100% small dots and 0% medium dots with an input of 33% (horizontal position) to 0% small dots and 100% medium dots at an input of 66%. The same logic applies to the medium-large transition with large dots replacing medium dots. With an input of 40% the Medium-Small transition curve is at 20% indicating that 20% of the dots placed will be medium size and the remaining 80% of the dots placed will be small.

Transition curve guidelines

Because transition curves define relative placement quantities, (i.e. the percent of dots actually placed) most positions on the chart are meaningful. The following guidelines may be useful:

1. The coverage curve defines an absolute coverage amount. The transition curves define relative amounts. Therefore, the coverage curve can have any value independent of the values of the transition curves.

2. The positions of the curves interact to achieve the output goals.

3. You can essentially eliminate dot sizes by placing transition curves on top of one another,. For example, by placing the medium-large transition on top of the small-medium transition curve you turn the curve into a small-large transition (eliminating medium dots).

4. Because of guideline 3, each vertical position of the transition curves for smaller dot size transitions should always be *higher or the same as the position* of the transition curves for larger dot size transitions.

5. The slope of the curves can be flat. However, for each horizontal position in the chart, at least one of either the coverage curve or other transition curves should have a non- horizontal slope. In other words, at least one of the curves should be changing. Otherwise there will be no change in actual output for differences in input.

6. The output density should increase with increasing input coverage. Generally, it is a good idea for the transition curves to either be horizontal or go up (increase). Otherwise, you will be placing more of the smaller dots than the larger dots with increased input coverage.

Figure 3 is an example of some Variable Dot curves that differ widely from the curves shown in Figure 1 and 2. In this case the coverage curve goes diagonally from (0,0) to (100, 100) representing a steady and consistent increase in dot coverage for each input. Reading the chart from left to right, the two transition curves are at 100% between horizontal positions 0% and 35%, which indicates that 100% of the dots placed in this coverage area should be large. At 35% (actually 35.0001%), the medium-large transition curve drops to zero and remains there while the small-medium transition curve stays at 100% until a horizontal position of 68%, which indicates that 100% of the dots between 35% and 68% coverage should be medium. At about 68%, both the small-medium and medium-large transition curves are 0%, indicating that 100% of the dots between 68% and 100% coverage should be small.

The output below the chart in Figure 3 confirms the lower coverage dots are all large dots, the middle coverage dots are all medium sized, and the near solid coverage dots are

all small. We also see that the tone ramp of the patches does not steadily increase in density with increasing input coverage because the transition curves are going down rather than up.

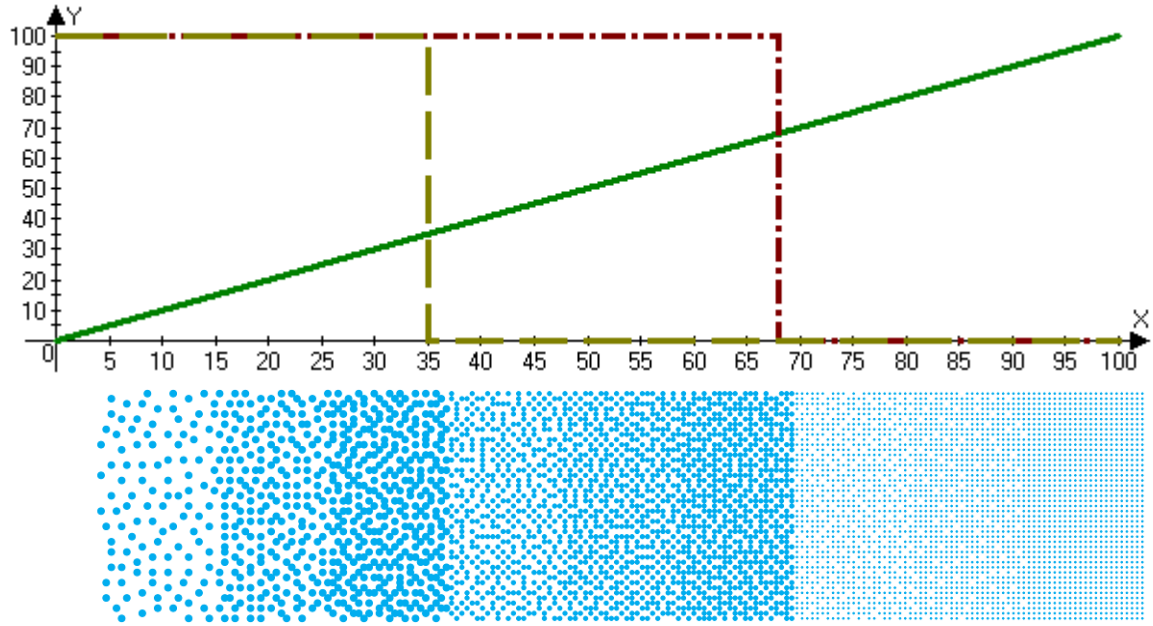


Figure 3 – Example output showing separate control of coverage and dot size selection

Variable Dot Settings in Relation to Ink Restrictions

Ink Restrictions are built upon the dot coverage and dot size use defined by the Variable Dot Settings. This means that the output of Ink Restrictions become the input to the curves in Variable Dot Settings.

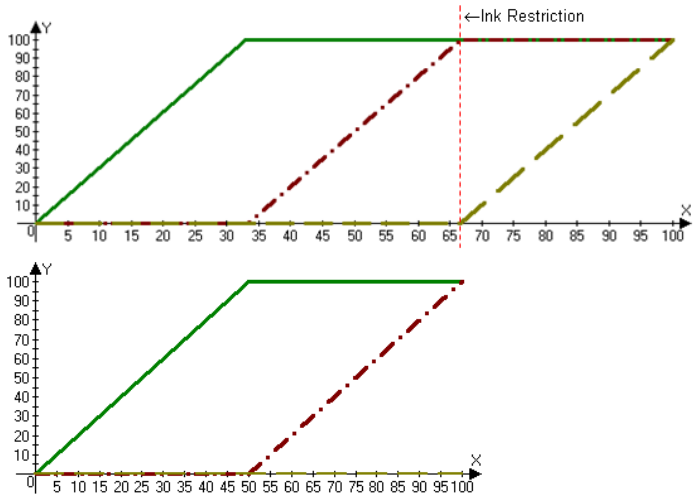


Figure 4 – Identical results are achieved when an ink restriction results in limiting ink to 66% ink (Top chart) and setting up a Variable Dot configuration to use no large dots (Bottom chart)

It is not as important that the Variable dot settings control the ink limiting and the default tone scale, because the Automated Ink Restrictions will perform these steps going into calibration.

Ink Limiting

There are two ways to prevent use of the large dot sizes, as shown in Figure 4. An ink restriction resulting in a 66% ink coverage is applied to the same default variable dot curves from Figures 1 and 2. The remaining curve below this ink restriction is identical to the second way of achieving this goal by defining a variable dot curve setup where no large curves are enabled (flat medium-large curve at 0%). The upper method requires that the ink restrictions are set up appropriately so that the ink restriction curves do not exceed 66%. The lower method ensures that large dots can never be used. However, with the upper method the ink restriction can be adjusted to possibly use some small amount of large dots (possibly to improve output quality). This is more difficult to accomplish if the limiting is in the variable dot setup, as changes to this will require re-printing and re-measuring the ink restriction swatch.

Tone Control

Any tone mapping performed in Variable Dot Setup will be adjusted to the same output because the Automated Ink Restrictions perform tone mapping to achieve a linear density going into calibration.

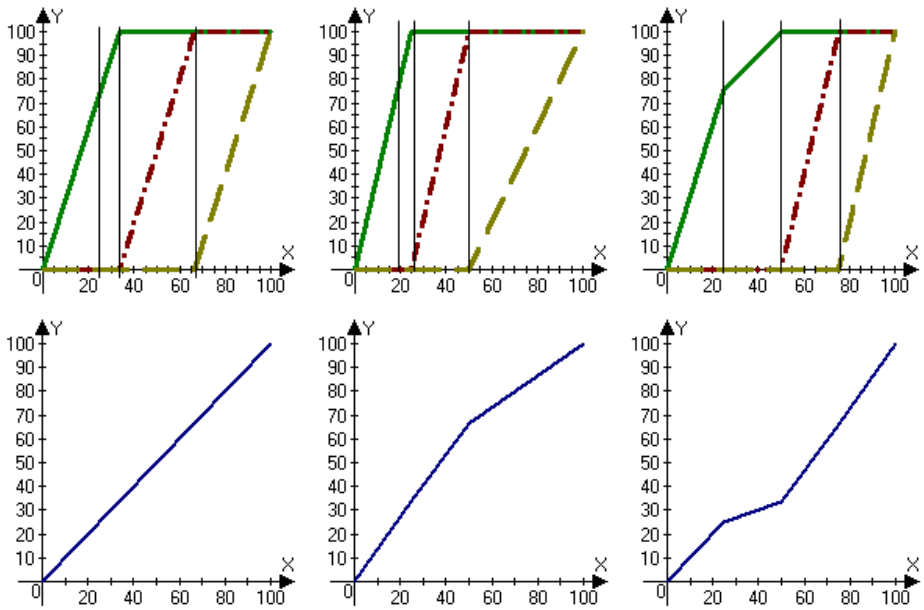


*Figure 5 – Examples of variations of semi-equivalent variable dot curves (top), and tone mapping adjustment curves **t(x)** that achieve variations (bottom)*

Mathematically speaking, tone mapping is performed by applying a tone mapping function ***t(x)*** to the input of the curve functions ***f(x)***. Thus, the final output of ink restrictions can be expressed as ***y=f(t(x))***. All curve functions that can be expressed as a

tone mapped version of another curve function, will result in identical output after ink restrictions are applied.

The top row of Figure 5 depicts various Variable Dot Setups that will result in identical output after ink restrictions are applied. As long as the differences involve the horizontal movement of points on all of the curves (both coverage as well as transition curves), their differences can be expressed as a tone mapping adjustment curve. The bottom row of Figure 5 displays the tone mapping functions which were applied to the curves depicted in Figure 1 & 2 resulting in the corresponding curves above each tone curve.

Generally, it is only important to define the relative coverage and dot sizes when defining variable dot usage. Time spent trying to achieve differences in final tone output will essentially be wasted. If you desire to achieve specific tone mapping goals, it is recommended that the target densities in the calibration step be adjusted.

Considering Printed Output

The simulated output in Figure 2 assumes that the printer is capable of accurately placing all dots in exact locations. In practice, there are many variables that cause printed dots to shift location from the ideal, exact location. Figure 6 displays a comparison between a simulation of the exact, ideal placement of dots with a simulation where the dots have some minor random perturbation to them, which results in a jumble of the pattern in the 33% and 66% patches.

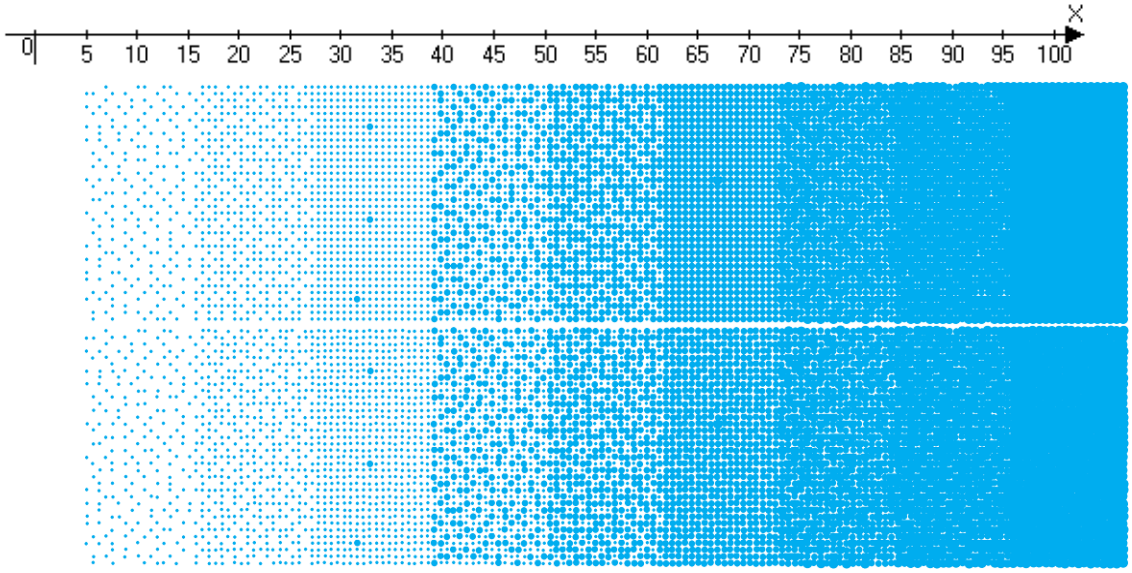


Figure 6 – Difference between ideal placement of dots (top) and placement with slight random variations (bottom) better simulating the variability in actual printing conditions

Note: Since printers are more likely to have some variability in the placement of dots all remaining simulations in this document will have the same random perturbations applied to them.

Making a Difference with Variable Dot Settings

Since tone mapping and ink limiting are not ideal objectives for variable dot settings, the remaining aspect that can be controlled is graininess and output quality. We will look at making progressive changes to the default curves from Figures 1 & 2 and evaluate the differences to better understand the effect on the output.

For completeness, we repeat these curves and simulated output in Figure 7. These are the baseline curves which we will call T0B0.

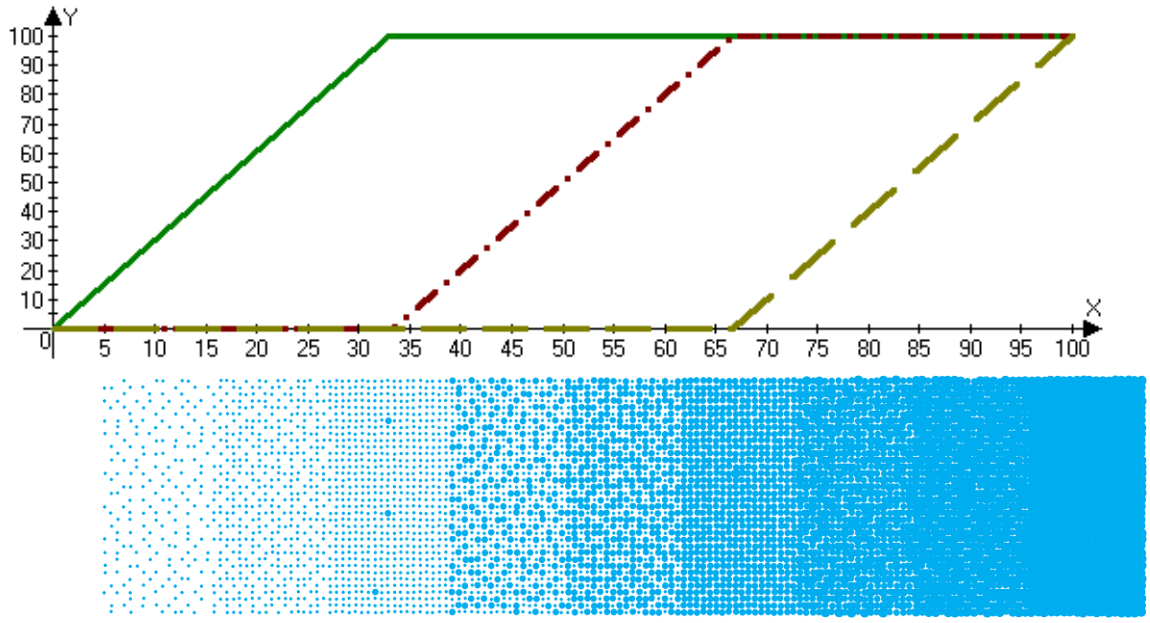


Figure 7 – Default Variable Dot curves (T0B0)

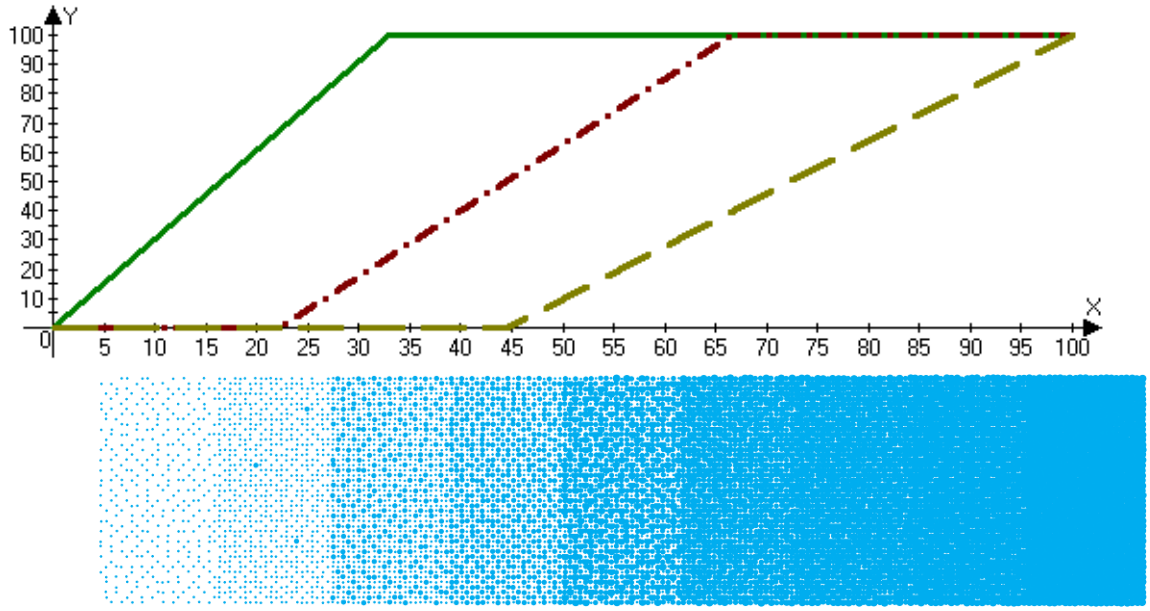


Figure 8 – Variable Dot curves with bottom points shifted 1/3 left from default curves (T0B1)

In Figure 8, the bottom points are shifted 1/3 of the way to the left while leaving the top points alone. We will denote this as T0B1 indicating a shift of the bottom curves. (Note: This differs from the left-most chart in Figure 5 in that the bottom transition point of the large-medium curve is no longer the same as the top transition point of the small-medium curve).

In Figures 9 and 10 are depicted curves labeled T0B2 and T0B3 indicating further shifting of the bottom curves more and more to the left until both the transition curves start at point (0, 0) in Figure 10 (T0B3).

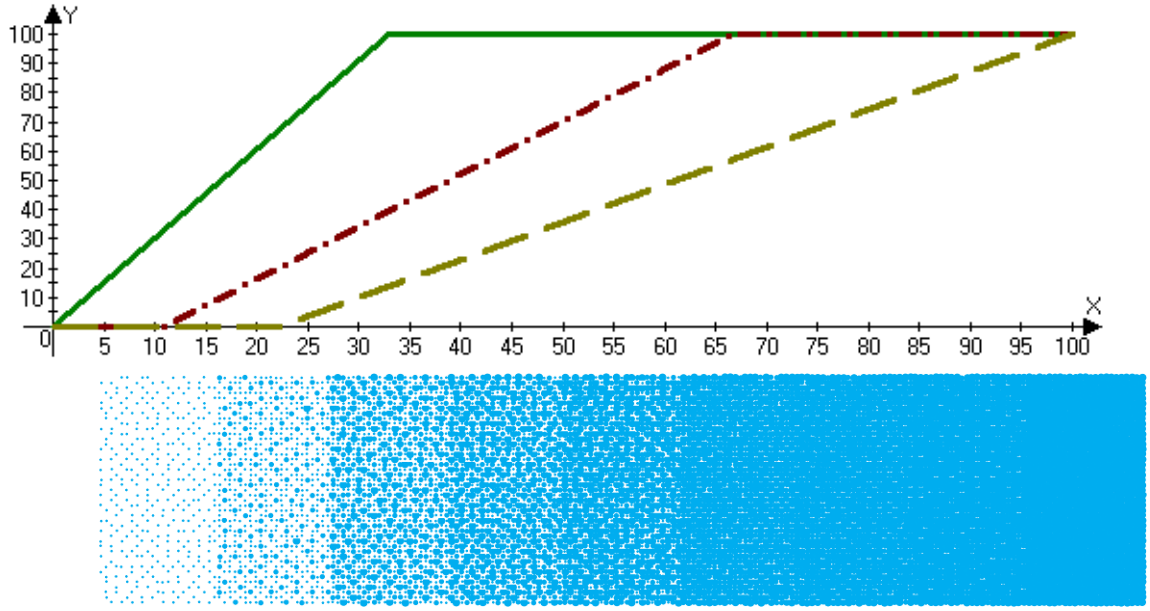
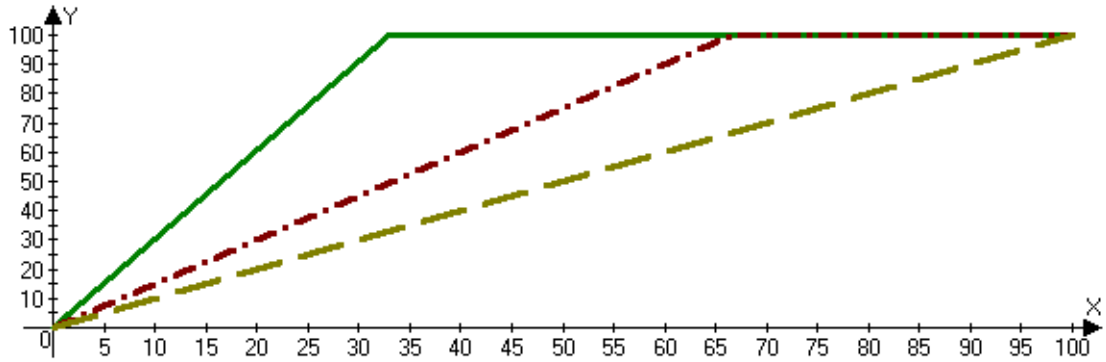


Figure 9 – Variable dot curves with bottom points shifted 2/3 left from default curves (T0B2)



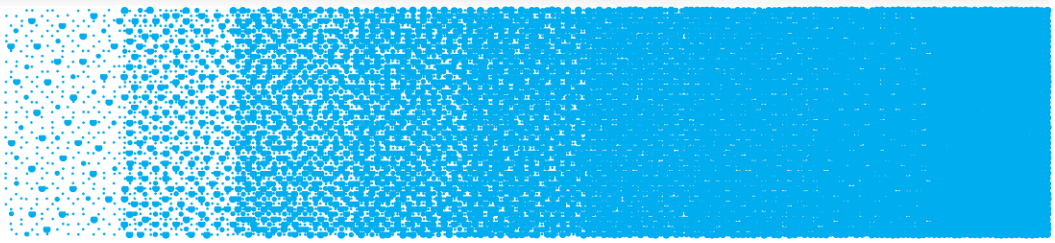


Figure 10 – Variable Dot curves with bottom points shifted all the way left (T0B3)

In order to compare and contrast the differences as the bottom transition points are shifted to the left the simulated output for each set of curves (with their names to the right) are placed together in Figure 11.

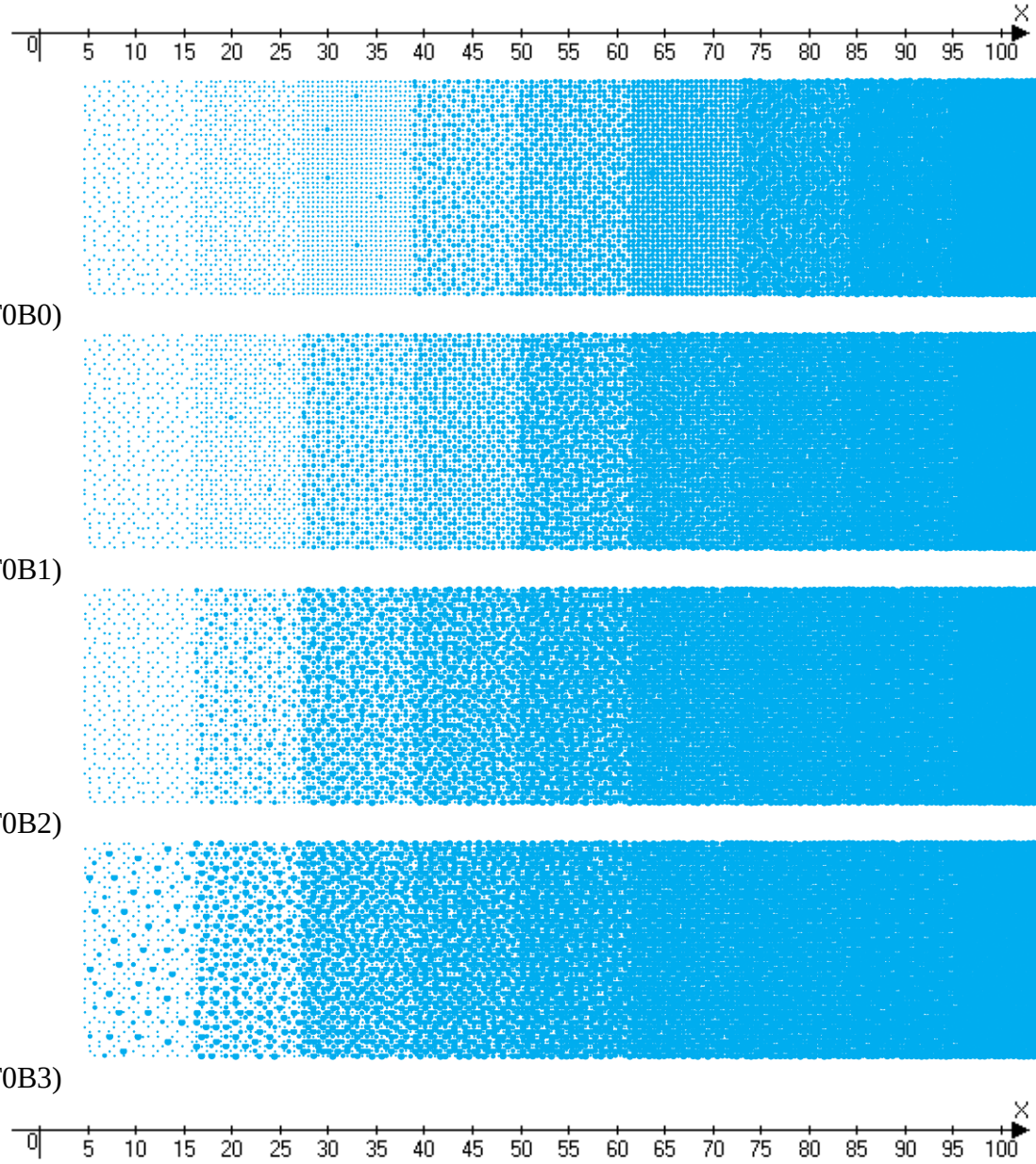


Figure 11 – Comparison of output as Variable Dot curves' bottom points are shifted left

There are several important points to highlight from this comparison:

1. The coverage does not change. There are the same numbers of dots in corresponding patches of the compared variable dot simulations.
2. As the transition point shifts to the left larger dots are used earlier.
3. As the transition point shifts to the left the corresponding patches get grainier. (IE compare at 33% patches).
4. The T0B0 curves result in the least grainy (smoothest) output.
5. Since the patches have larger dots in them as the bottom transition point shifts to the left, the density increases in corresponding patches (with a change in the overall tone going into ink restrictions).

Alternatively, we can shift the top points of the curves to the right and leave the bottom points of the curves in place. The top curves (including the coverage curve) are shifted 1/3 the way to the right in Figure 12. (Note: This also results in the top transition points occurring at different horizontal positions than the top transition points).

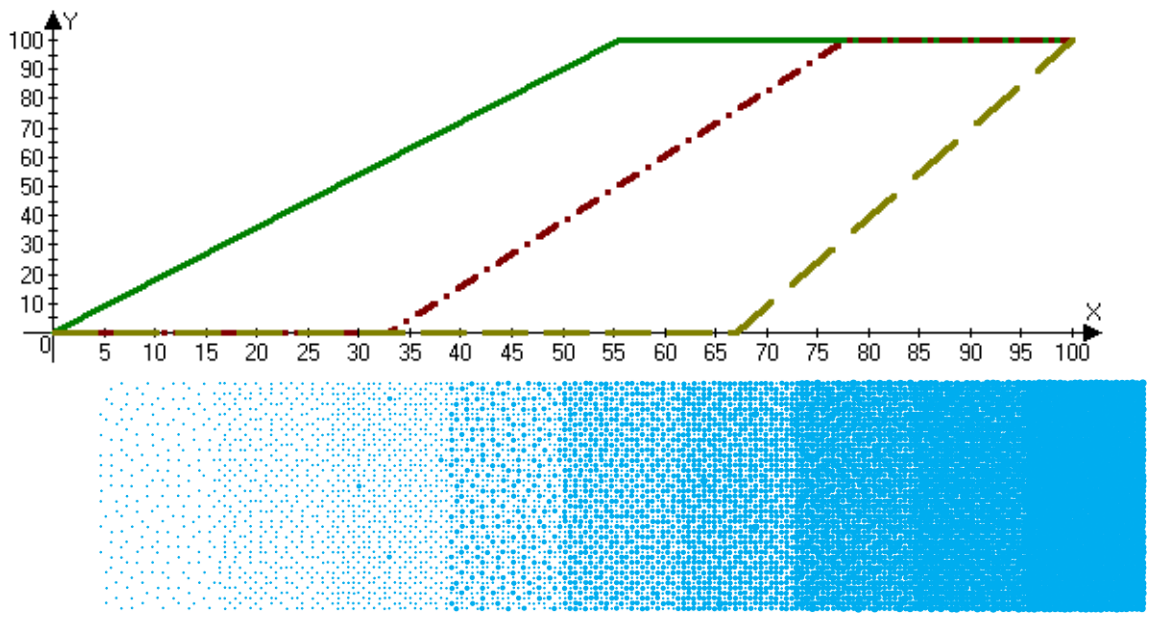


Figure 12 - *Variable dot curves with top points shifted 1/3 right from default curves (T1B0)*

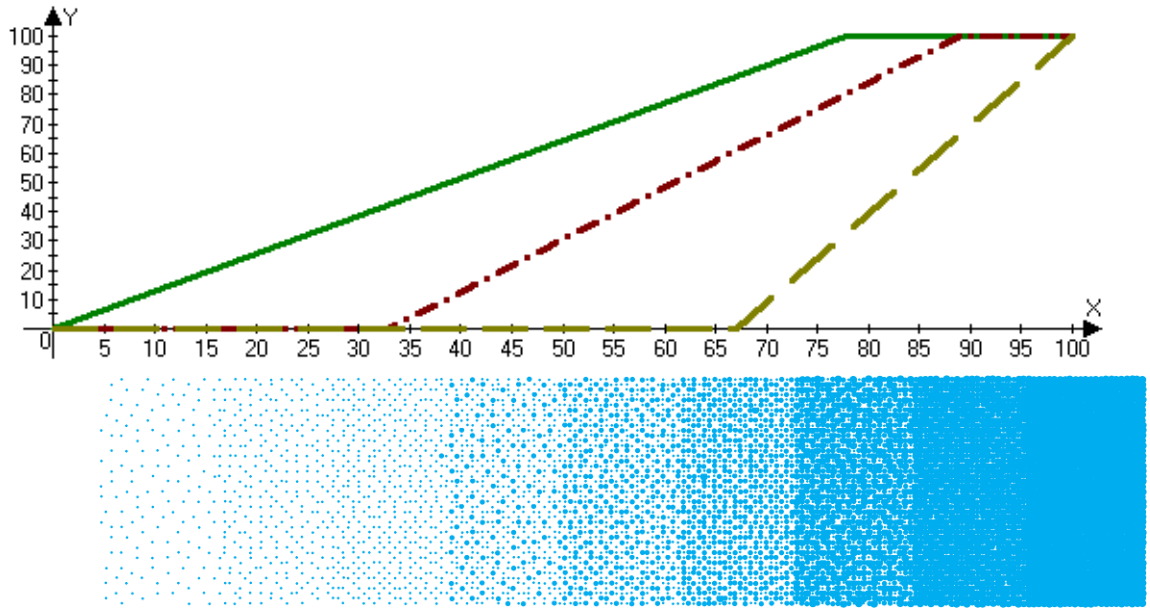


Figure 13 - *Variable dot curves with top points shifted 2/3 right from default curves (T2B0)*

The top curves (including the coverage curve) are shifted all the way to the right in Figure 14.

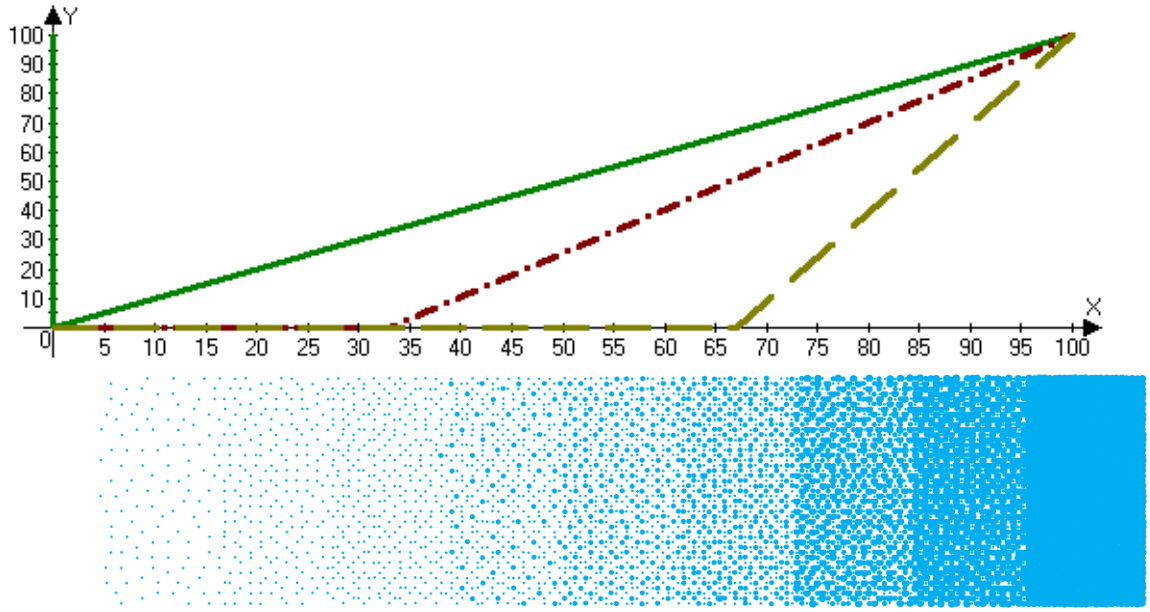


Figure 14 – Variable Dot curves with top points shifted all the way right (T3B0)

In order to compare and contrast the differences as the top transition points are shifted to the right of the simulated output for the set of curves, T0B0 through T3B0 are placed together in Figure 15.

There are several important points to highlight from this comparison:

1. In contrast to Figure 11 the coverage does change. Because the coverage curve shifts to the right there are more places without dots in corresponding patches.
2. Similar to Figure 11, as the transition point shifts to the right the corresponding patches also get grainier. (IE compare at 33% patches).
3. Similar to Figure 11, the T0B0 curves result in the least grainy (smoothest) output.
4. In contrast to Figure 11, since the starting point of the transition curves remains the same the dot size makeup of the patches remains fairly constant.
5. In contrast to Figure 11, since the patches have fewer dots in them as the top coverage point shifts to the right the density of corresponding patches decreases (with a change in the overall tone going into ink restrictions).

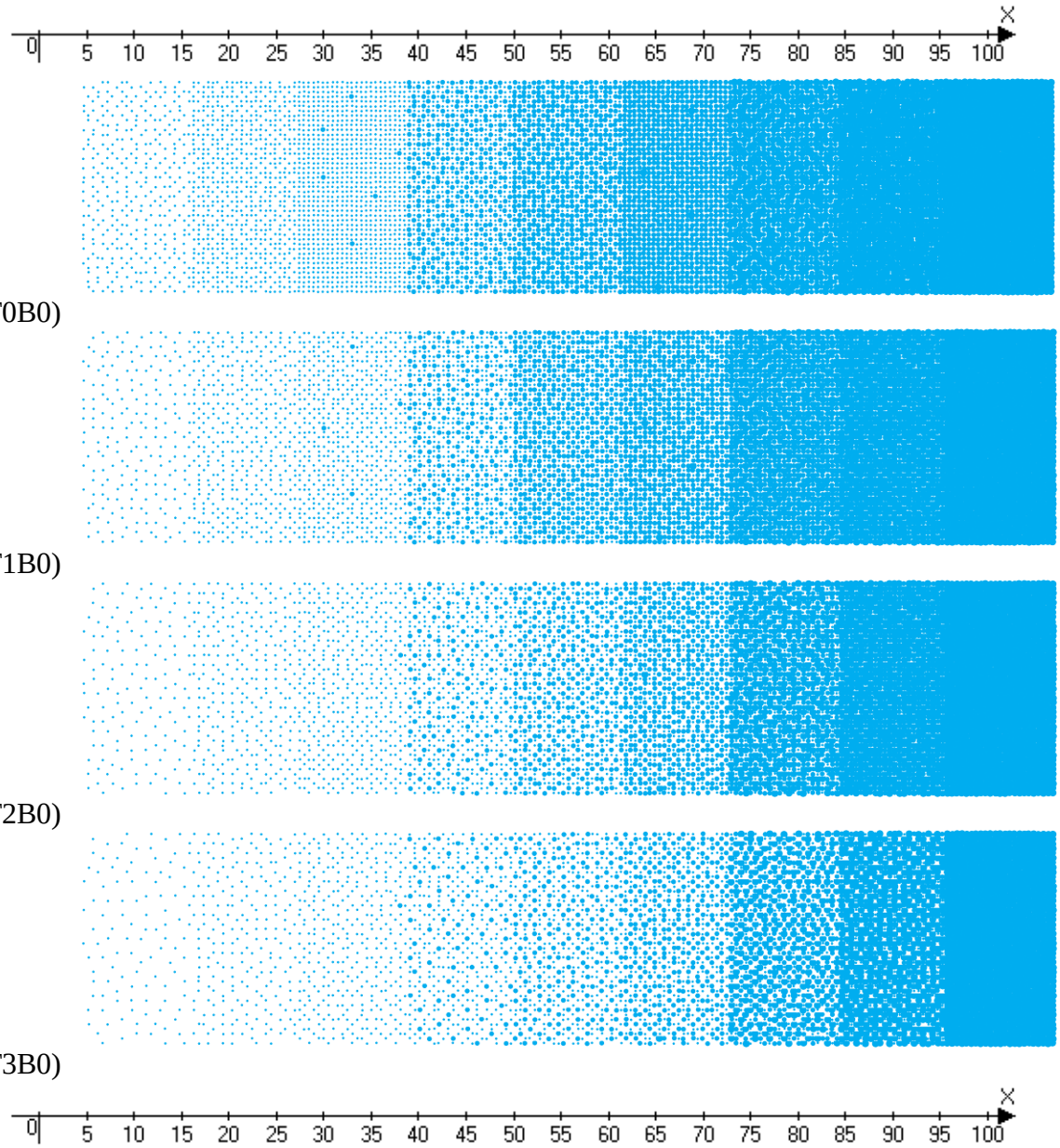


Figure 15 – Comparison of output as Variable Dot curves' bottom points are shifted left

Combining the results from Figures 11 and 15 we find that shifting top or bottom curves increases graininess, shifting top curves results in lighter output, and shifting bottom curves results in darker output.

Figures 16 through 18 show the results of the curves and output results when both the top and bottom are shifted by 1/3 and 2/3 then all the way towards the curves as a diagonal line.

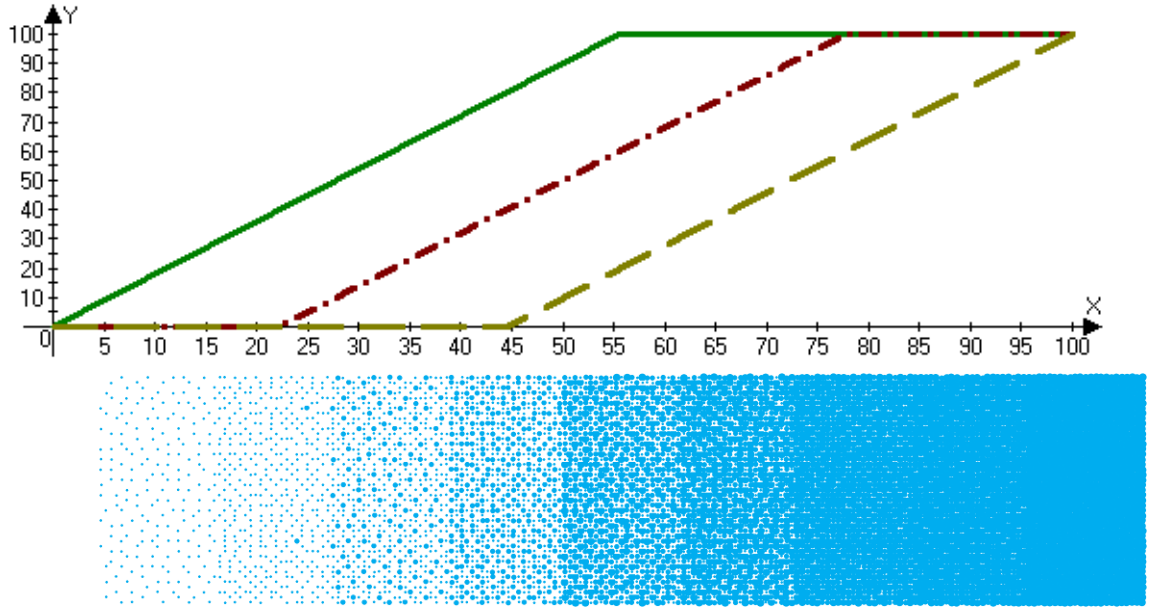
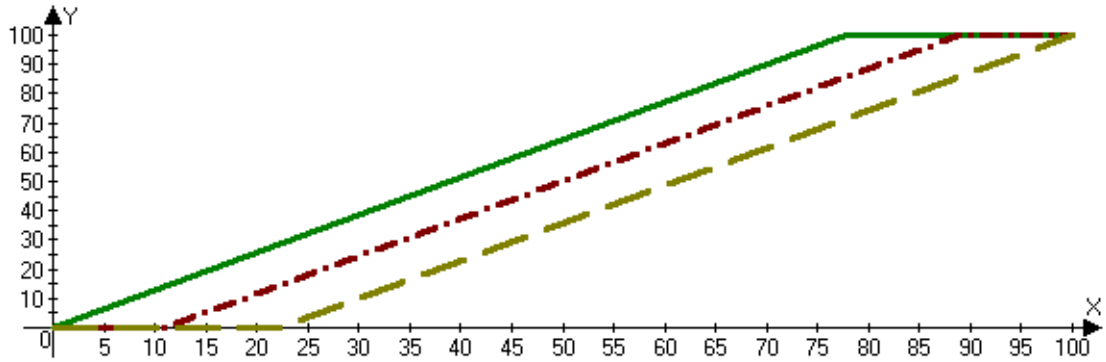


Figure 16 - Variable dot curves with top points shifted 1/3 right and bottom point shifted 1/3 left from default curves (T1B1)



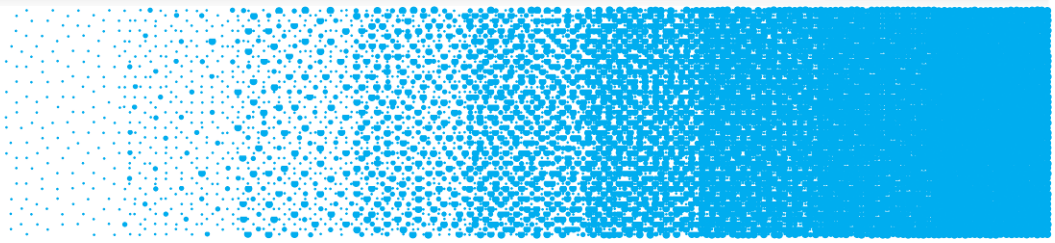
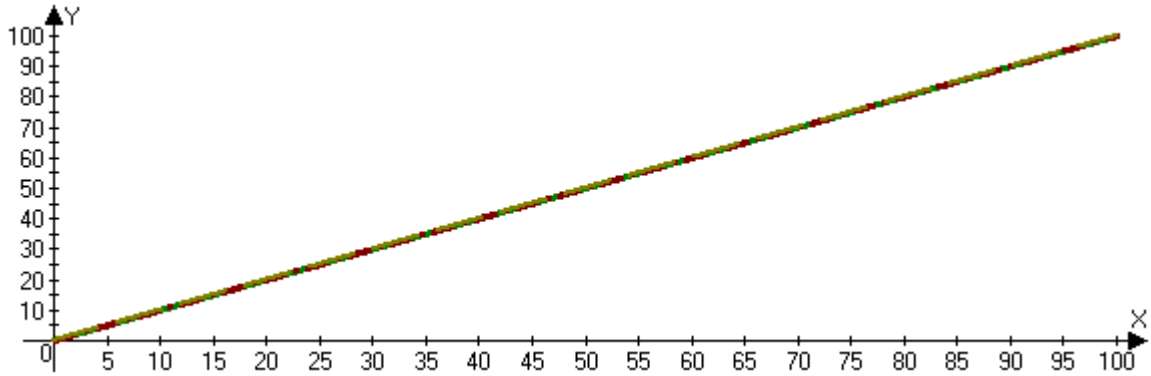


Figure 17 - Variable dot curves with top points shifted 2/3 right and bottom point shifted 2/3 left from default curves (T2B2)



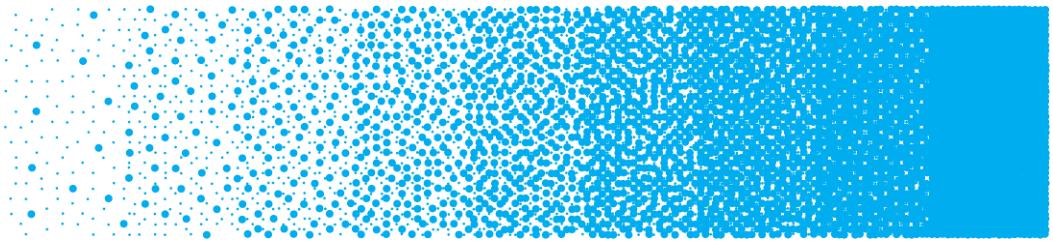


Figure 18 - Variable dot curves with top points shifted all the way to the right, and bottom point shifted all the way left from default curves (T3B3)

In order to compare and contrast the differences as the top and bottom transition points are shifted, the simulated output for the set of curves T0B0 through T3B3 are placed together in Figure 19.

There are several important points to highlight from this comparison:

1. Similar to figure 15, the coverage appears to change resulting in more empty dots in more saturated patches.
2. Similar to Figure 11, the starting point of using larger dots appears to move to the left.
3. Similar to Figures 11 and 15, the corresponding patches get grainier. (IE compare at 33% patches).
4. Similar to Figure 11 and 15, the T0B0 curves result in the least grainy (smoothest) output.
5. In contrast to Figures 11 and 15, the tone differences between moving the top right and the bottom left appear to cancel and the overall tone scale remains fairly constant.

6. As the curves get closer and closer to the diagonal, fewer and fewer of the medium size dots are used until no medium size dots are used when the curves are all diagonal (T3B3). (Note: This progression can be continued by pulling the start transition curves up (leaving the coverage curve at a diagonal) from the (0, 0) point towards the (0, 100) point resulting in using fewer small dots and more large dots until the transition curves are horizontal at the top with only using large dots).

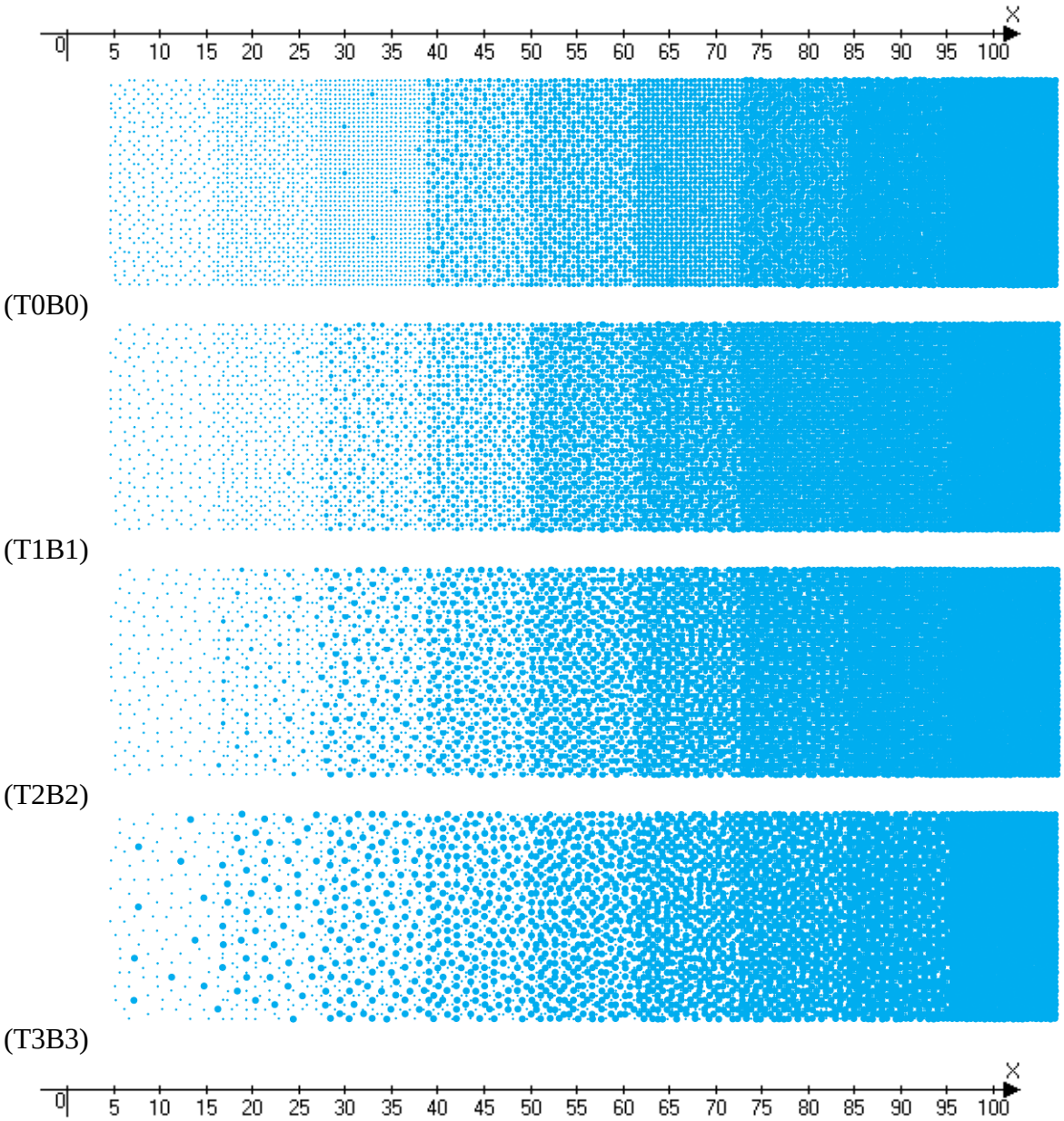


Figure 19 – Comparison of output as Variable Dot curves become more diagonal

Banding and Variable Dot Setup

When looking at figures 11, 15, and 19 it appears that the T0B0 appears to achieve the smoothest output. This can be attributed to the uniform, regular pattern that is formed by having a solid fill of uniform dot sizes.

However, because a solid fill of small and medium dots is uniform and regular, this particular pattern is most susceptible to inconsistencies in dot placement. To show how this can be a problem the output, Figure 19 was adjusted so that dots in rows 6-10, 16-20, 26-30, and so forth are offset by 1/3 of a dot placement height. This is somewhat akin to the pass advance being slightly off. The results are shown in Figure 20.

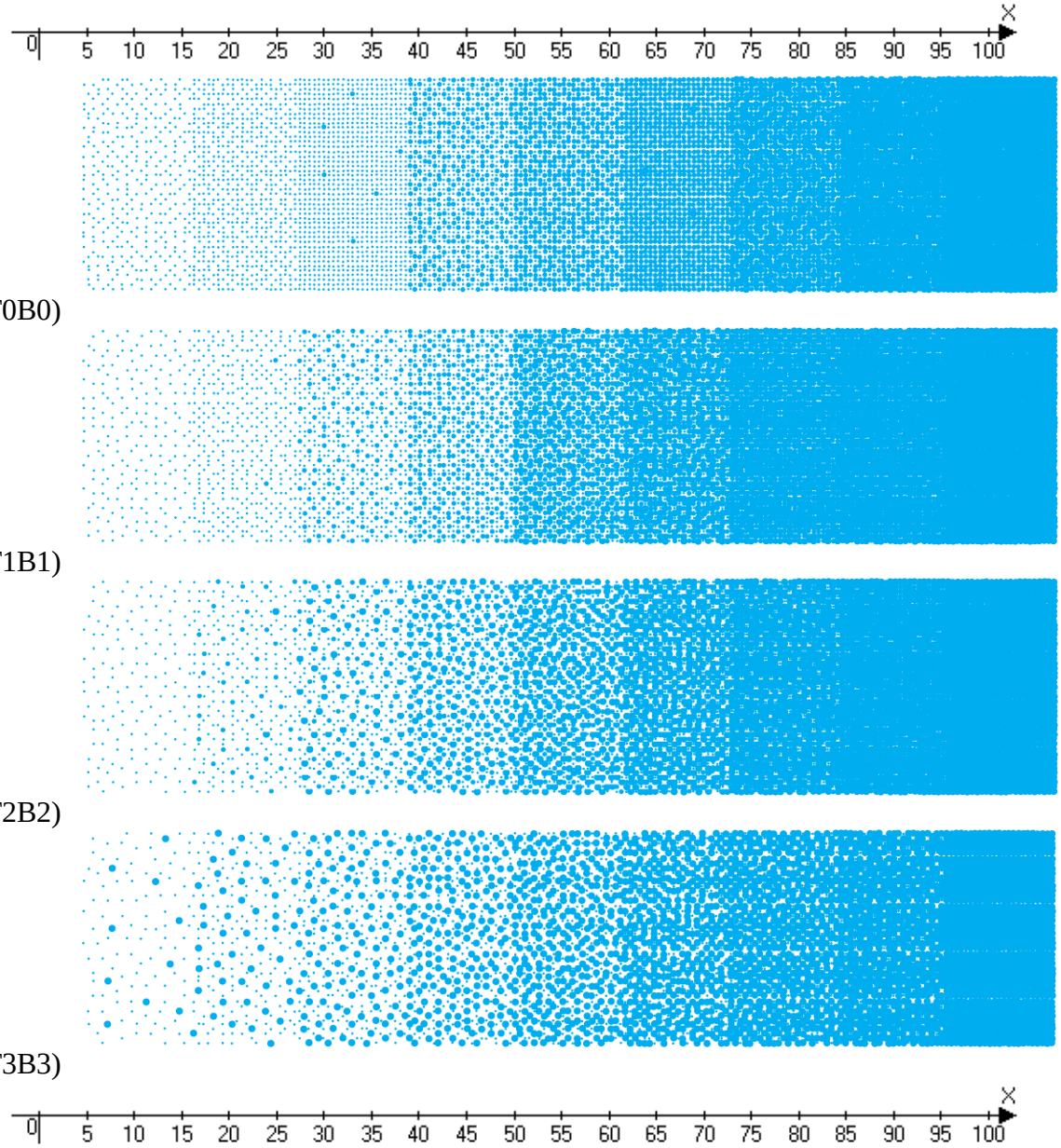
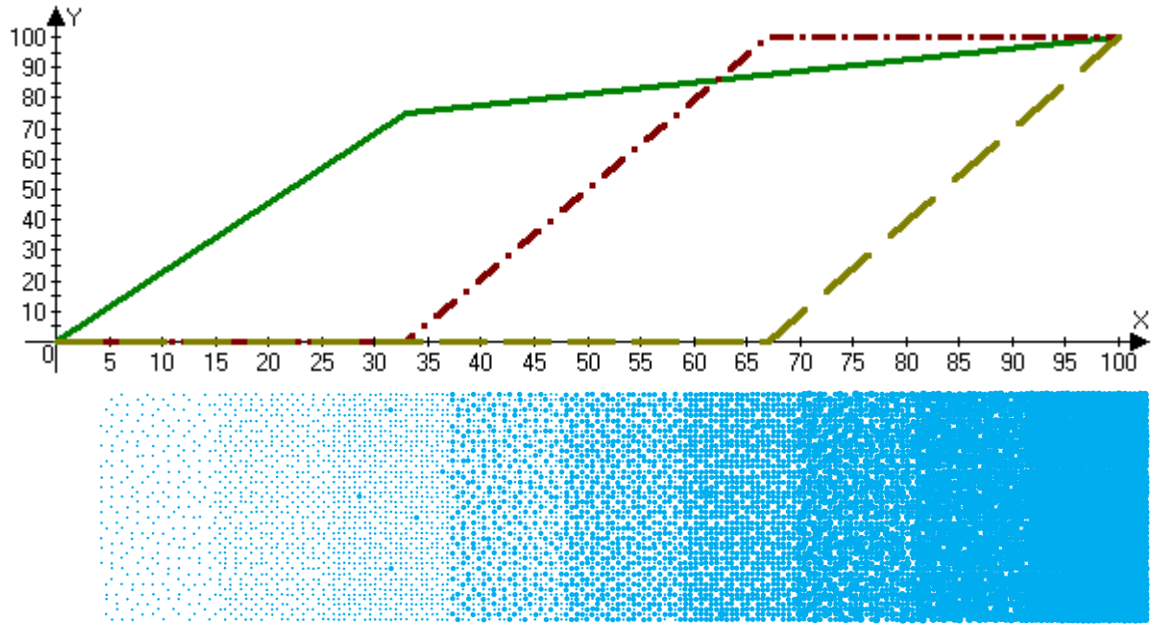


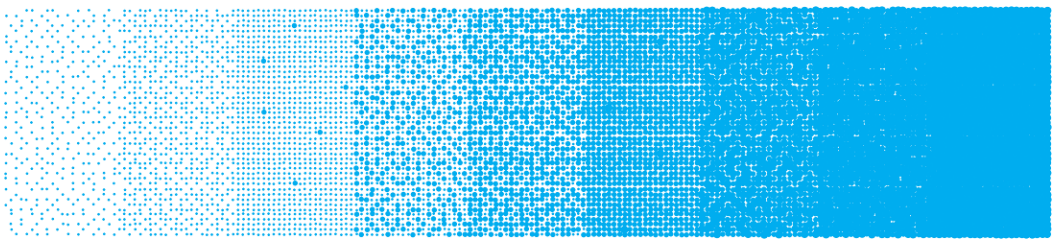
Figure 20 – Simulation of 1/3 dot placement offset banding with comparison of output as Variable Dot curves become more diagonal

As can be seen in Figure 20, the uniform regular placement of dots (in the T0B0 curve configuration) significantly magnifies the problems with alignment. By adding a bit of graininess to the configuration, we see that the misalignment is less noticeable. The result is it may be advisable to use a grainier (less smooth) Variable Dot Curves when print alignment is not entirely perfect in some cases.

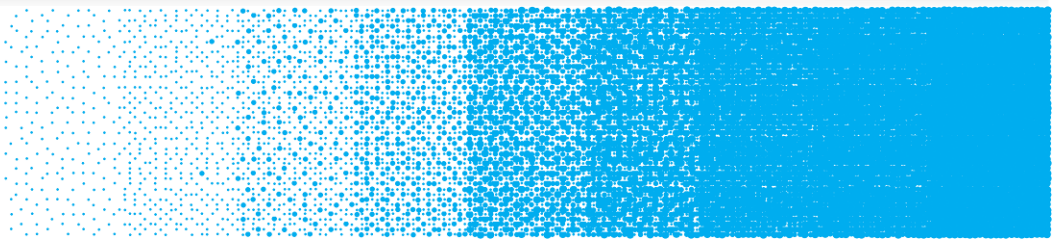
An alternative approach might be to leave the transition curves found in T0B0 alone and simply adjust the coverage curve so that a solid coverage of dots does not occur until the 100% input coverage point. An example of this approach is shown in Figure 21 along with the associated T0B0 and T1B1 output from Figure 20.



(C75)



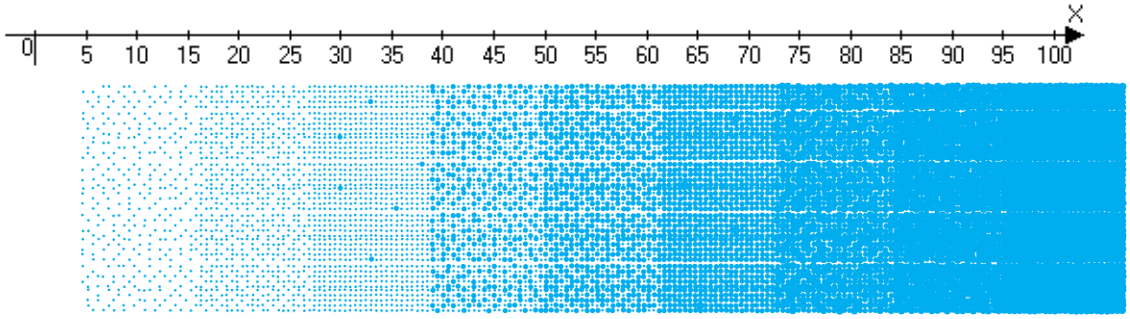
(T0B0)



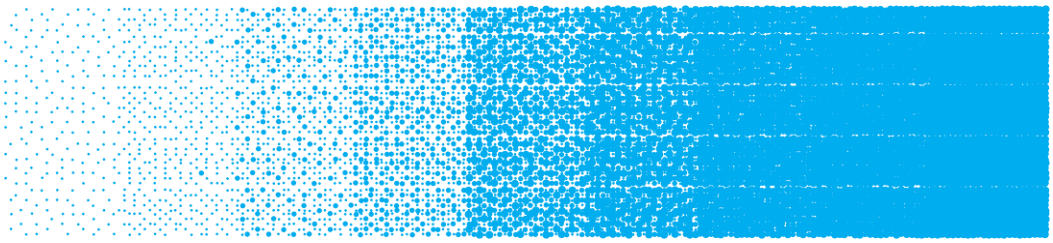
(T1B1)

Figure 21 – Banding example with the same Transition curves as in T0B0 with reduced output coverage that prevents a solid fill until 100% input coverage compared to T0B0 and T1B1

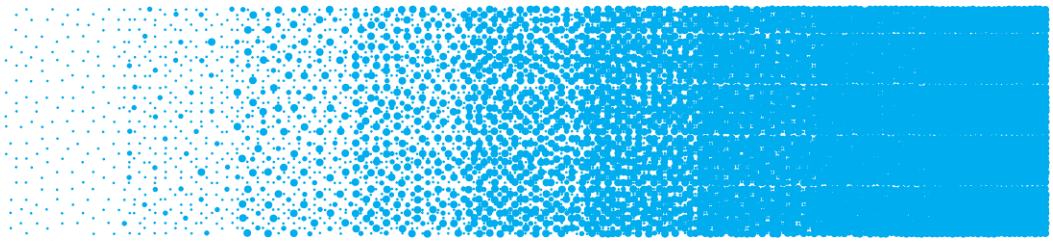
Note that although these techniques can be used to reduce some printing artifacts they will not necessarily be eliminated. The same comparisons shown in Figure 20 are shown in Figure 22 where the banding offset is periodically off by 2/3 of a dot placement unit. In this case there is some improvement in not using the T0B0 curve configuration. However, banding remains noticeable for all configurations. In some cases the printer itself might simply be out of alignment and is in need of adjustment or servicing to return to proper alignment.



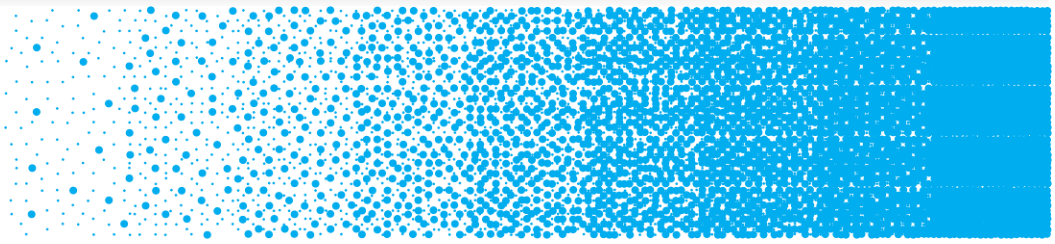
(T0B0)



(T1B1)



(T2B2)



(T3B3)

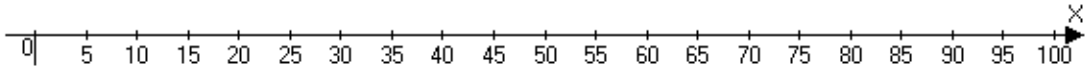


Figure 22 – Simulation of 2/3 dot placement offset banding with comparison of output as Variable Dot curves become more diagonal

Conclusion

Generally, the default curves defined for printers are set up to get the smoothest possible output. However, in some instances it may be beneficial to define custom Variable Dot curves when using the new Automated Ink Restrictions in Media manager.

When making changes to variable dot curves, it is not generally important to be concerned with tone control or ink limiting as these are controlled more effectively in later stages of the profiling process. The best use of the Variable Dot Control Tool is to attempt to reduce graininess and banding.

As the curves are flattened to a diagonal, an increase in graininess may gain you reduced banding and artifacting.