Improving bar code quality

The guidance documented here is intended to help packaging designers and printers achieve good quality printed bar codes on their packaging and products. This advice is particularly relevant to bar codes used to identify products at the consumer level using conventional printing techniques, but it could also be applied to traded unit bar codes printed directly on to the outer packaging. The information does not cover the production of bar codes printed using on-demand printing technologies on labels.

The printing of dimensionally accurate bar codes requires a complete understanding of the production process from the original design and use of the bar code image in the master artwork through the pre-press and printing process. In addition to achieving dimensionally accurate bar codes, it is also vital to ensure that correct data is encoded into the right bar code type and that suitable colours are used for printing the bars as well as for the background behind the bars, however, these items are not dealt with in this document and the designer should consult the GS1 UK Bar Code – Getting it Right document for more on these issues.

Before making a bar code master image to import into artwork, it is necessary to determine the appropriate size for the bar code and to ensure that bars have been compensated for the growth that they will experience during the plate making and due to ink spread when printed. There are several variables to consider and it may be necessary to test out the production and printing process to establish the characteristics that will affect the final print.

Different printing processes will tend to give different amounts of ink spread with flexographic printing tending to give more than offset lithographic printing, for instance. The material being printed on will also affect this though so running tests will give the best indication of what compensation will be needed for the printing stage of the process. Printing processes that do generate larger amounts of ink spread should not use bar codes of the smallest size or magnification, for instance a magnification of 110% or more for an EAN-13 would be best suited for flexographic printing.

The creation of printing plates, whether they are made directly computer-to-plate or from film of artwork, will also introduce bar growth that will need to be compensated for. As with ink spread, this can best be determined by running tests and either the film could be measured using suitable equipment or printing plates made and the final output measured in order to gauge the bar growth caused by the plate making and the ink spread processes.

With bar codes requiring a high degree of dimensional accuracy, the resolution with which the artwork is output onto film or directly to plate will need to be taken into consideration when choosing both the size of bars and the amount of compensation. If the artwork is also processed in some way to create an intermediate saved version, such as when creating a PDF copy, then the resolution used for creating the PDF (if it is used for the final creation of the output to film or plate) should match that of the output device.

Matching the widths of the bars of the symbol to the resolution of the output device is a matter of working out the distance between pixels for the output device. An example would be an imagesetter with an output resolution of 1270 dots per inch. The pixels for this resolution are 0.02 mm (20 microns) apart, so it is important to choose an appropriate magnification to suit this resolution and this is achieved by selecting a bar width that is a multiple of the pixel separation distance. A 100% magnification EAN-13 symbol has bar widths that are a multiple of 0.33 mm (330 microns) and this cannot be achieved with pixels that are spaced at 0.02 mm. Therefore a magnification of 97% or 103% should be chosen instead.

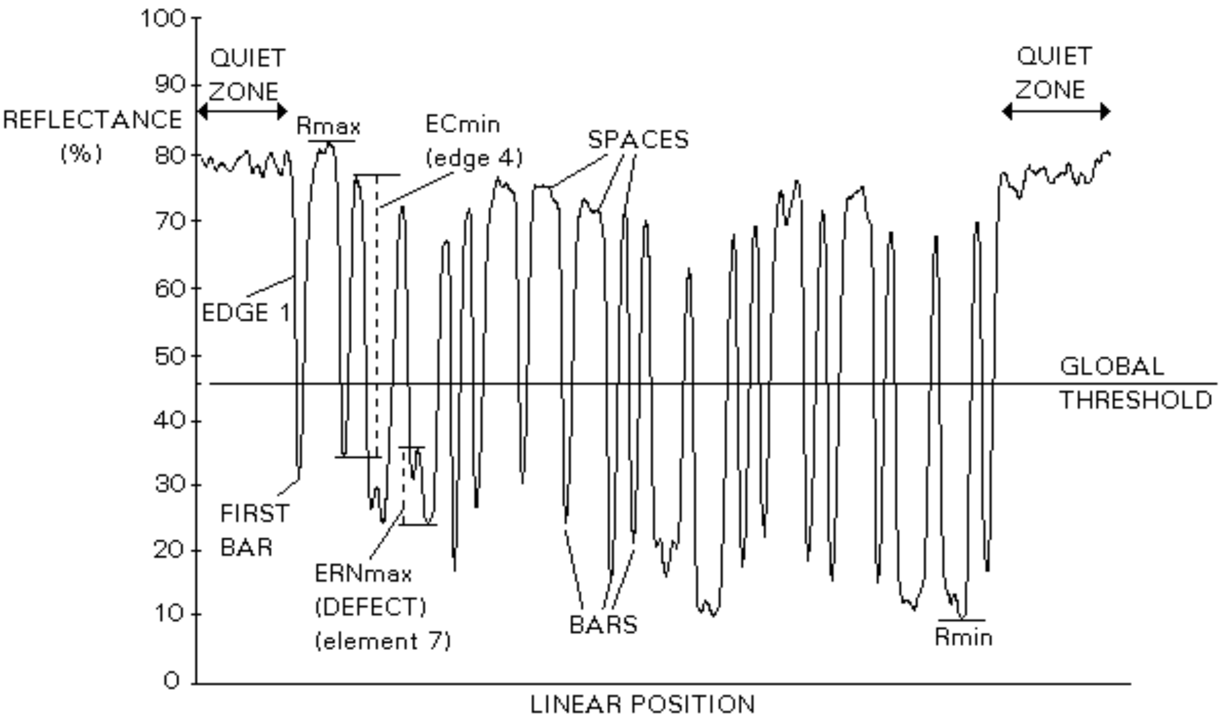
Similarly any compensation should be a multiple of the pixel separation distance, so if it is estimated that the bars should be reduced in size by 0.05 mm to compensate for bar growth and ink spread, then 0.04 or 0.06 mm should be chosen instead. In most cases it is preferable to choose a value of compensation which makes the bar widths slightly undersize rather than oversize, so in the above example the choice of 0.06 mm reduction of the bar widths would probably be the best compromise.

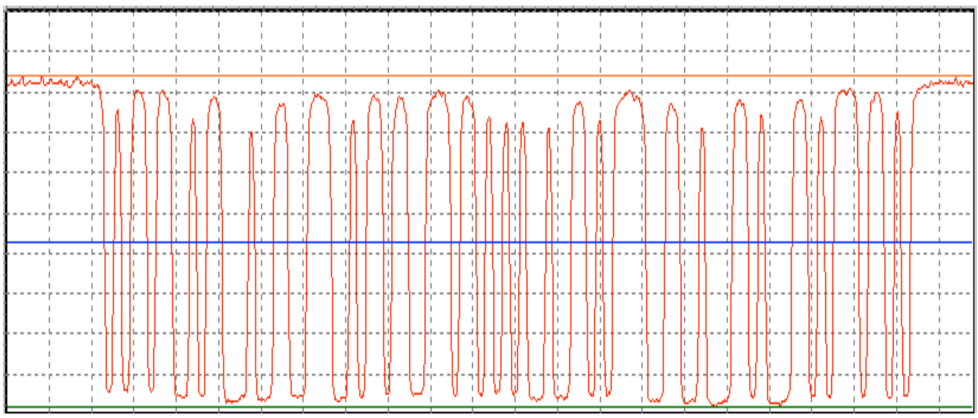
What is a scan reflectance profile?

A scan reflectance profile (SRP) is a graph of the reflectance values of a bar code. The horizontal axis corresponds to the width of the bar code, and the vertical axis shows how much light is reflected back to the reader by each bar and space.

If bar codes were perfect, the height of the peaks in the graph (the spaces) would be exactly the same, and the depth of the troughs would also be uniform.

The SRP below is exaggerated to show how defects show up in the graph. The second one shows a more typical SRP of a real world bar code.





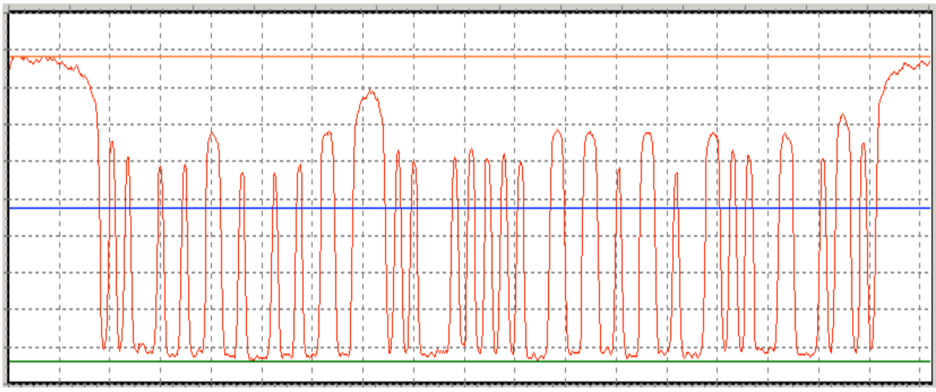
This graph shows the reflectance of the darkest bar with the horizontal green line, the reflectance of the palest spaces (in this example, the quiet zones) with the horizontal orange line, and the halfway point (the global threshold) is shown by the horizontal blue line.

Improving modulation grades

Modulation is the hardest verification parameter to fully understand, together with what affects it. Problems are caused by incorrect widths of the bars or spaces, or by the choice of the material substrate.

A bar code will pass on modulation when all the spaces are seen as evenly white and the bars evenly black. If there are parts of the bar code that are much less black-and-white than the overall bar code, it will fail on modulation.

The SRP below shows the effect of modulation on the reflectance values; many of the white spaces are much less reflective than the light margins at each side of the bar code.



If there is too much ink spread, the narrow spaces will become even narrower and not appear as white as other wider spaces in the bar code. This means that there will be lower minimum edge contrast, while symbol contrast remains the same. Modulation is measured by comparing the edge contrast minimum to the symbol contrast.

In practice problems with modulation tend to be asymmetric, in that high reflectance peaks drop especially if the packaging material is either a glossy finish or allows light to travel into it, such as film (even when a background white out box is printed on the film behind the bars of the bar code). This poor modulation is worse on smaller bar codes, so a designer should aim to make EAN-13 bar codes of at least 100% magnification to help reduce this effect. Any bar growth will also worsen the modulation grade.

The cure is to increase the bar width reduction which will increase the width of the spaces.

Modulation problems occur most when printing onto film, and if the bar code is printed on a white background, light will pass through the bars and be reflected back by the white background. If the spaces are wide enough the score for modulation could be fine, but spaces that are too narrow will cause low reflection and poor modulation due to the good symbol contrast and poor edge contrast minimum.

There are three possible ways to try to avoid this:

1. Increase the opacity of the white background so that the thin spaces reflect more light and so improve the minimum edge contrast.

2. Increase the magnification factor (use a larger x-dimension) to widen all the spaces.

3. Increase the bar width reduction to produce wider spaces.

These approaches will only work if the film is semi-opaque. Placing the symbol over a white background would boost the apparent whiteness of the wider spaces but not have much of an effect on the narrower spaces. This means symbol contrast will be higher but the minimum edge contrast will still be poor, and result in a poor grade for modulation. If you were to place the symbol over a black background, all the white spaces will appear greyer; the symbol contrast will now be lower and so will be minimum edge contrast but the difference will not be so great, and the modulation score will increase.

If you still get poor modulation with the black background there is not much you can do if the symbol needs to be printed on the back of the film. You should try different materials that will let you print on the front surface so avoiding having film between the scanner and the printed symbol.

The choice of printing process makes a difference to the amount of bar width reduction that needs to be applied to the original film master bar code artwork. The following table can only provide a starting point as it is best to test the printing process using a 100% sized bar code with no bar width reduction, which is then measured using a verifier to find the bar width average growth. This information can be used to assess what is actually required.

Suggested BWR for EAN/UPC symbols

Method	BWR in microns	Minimum Magnification Factor (%)	Minimum x-dimension
Litho	0 – 25	80	0.26
Letterpress	25 – 40	90	0.30
Gravure	25 - 40	100	0.33
Flexo rubber	70	120	0.39
Flexo photopolymer	40	110	0.36
Silk Screen	100	140	0.46

Suggested BWR for ITF-14 symbols

Method	BWR in microns	Magnification factor (%)	Minimum x-dimension
Flexo rubber	150	100	1.016

The other area that needs addressing is the different type of output of the image setter that reproduces the bar code artwork or the laser printer that might produce the final product. The artwork is converted into overlapping dots and thus needs a small amount of compensation depending on the resolution of the image setter or printer. See the following table for guidelines:

Resolution (dots per inch)	Compensation amount in microns
1200 dpi	-21
1750 dpi	-15
2400 dpi	-11
2540 dpi	-10
3386 dpi	-8
4000 dpi	-6
5080 dpi	-5

What are defects?

Spots of ink in the quiet zones or spaces, or light areas in the bars, will cause a ripple in the scan reflectance profile at the point where the scan path crosses them. The greatest of these is referred to in the profile analysis as Element Reflectance Non-uniformity maximum (ERNmax). In the profile of a space, they show as a valley; in that of a bar, they show as a peak.

If this peak or valley approaches the threshold between light and dark, the risk of the element being seen as more than one, and of the scan failing to decode, increases. The use of the correct measuring aperture ensures that the affect of defects is not exaggerated or underrated. This will ensure that the diameter of the beam of light measuring the bar code is approximately 80% of the particular bar code's x-dimension.

The defect parameter measures the relationship of ERNmax to Symbol Contrast.
Defects = ERNmax/SC.

What is decodability?

The decodability parameter is the one verification parameter that is directly affected by dimensional accuracy. It is a measure of how close the widths of all the bars and spaces are to being perfect.

Each bar and space within the bar code will be assessed for its dimensional accuracy. For all the bars and spaces in an EAN-13 or EAN-8 symbol this decodability calculation uses measurements from the leading edge of one bar to the leading edge of the next bar and also from the trailing edge of one bar to the trailing edge of the next bar, and these measurements are known as edge-to-edge measurements. Ink spread is usually consistent on all bars and as a result these edge-to-edge measurements are not affected by such uniform bar growth. If the edge-to-edge decodability calculation gives a poor result it is often a sign that the size of the bars has not been well matched to the pixel sizes of the imagesetter.

In addition to the edge-to-edge measurements, some characters are also checked specifically for bar growth or shrinkage either of which might result in a poorer decodability grade for the symbol under test. A growth or shrinkage of just 15% can be enough to result in a grade being dropped for this parameter, so keeping bar growth or shrinkage within this tolerance is a good target to aim for. If modulation is already a problem, then any bar growth would make it worse, so on materials that suffer poor modulation a better target of print tolerance on bar growth would be 0% growth but down to 15% shrinkage.