# CREATING QUALITY BAR CODES FOR YOUR MOBILE APPLICATION

MOTOROLA

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# 1 INTRODUCTION

The rapid growth of Smartphones along with mobile Internet access has enabled new and exciting applications and services. In particular, the ability to send secure, machine readable information to a user's cell phone has enabled applications such as electronic ticketing, digital coupons, and digital loyalty programs. Advances in high resolution displays and bar code reader imaging technology have made the humble bar code an attractive and popular choice for transmitting, displaying, and reading such information. The bar codes used in these applications are referred to as mobile barcodes.

Managing bar code information on a cell phone's LCD introduces many new challenges as compared with printed bar code applications. Such challenges include generating readable bar codes on an increasing number of displays and a current lack of international standards.

This whitepaper sheds light on the challenges and pitfalls of generating and displaying bar codes on cell phone LCD screens, and discusses common problems and specific bar code design examples.

# 2 PRINTED BAR CODES VS. MOBILE BAR CODES

The ubiquitous printed bar code has been in existence for over 30 years. Printed bar codes can be easily read using either laser scanners (1D and PDF code types) or imager scanners (all code types). Printed bar codes represent static data and are typically designed once and printed multiple times using standard printing processes. The quality of the bar code can be monitored and tested to international printing standards[2] using commercial bar code verifiers to ensure readability.

Mobile bar codes, on the other hand, are typically generated spontaneously and displayed on a cell phone's LCD as shown in Figure 1.


**Figure 1 – Bar code displayed on a cell phone**

Unlike printed bar codes that reflect and absorb light, mobile bar codes displayed on an LCD actively emit light. Because mobile bar codes emit rather than reflect light, readers based on imaging technology are usually required. In addition, a single LCD pixel is typically constructed from three rectangular color sub-pixels as shown in Figure 2. Bar code readers may need to address additional "noise" resulting from the underlying pixel structure, along with reflections and distortions exhibited by the display.

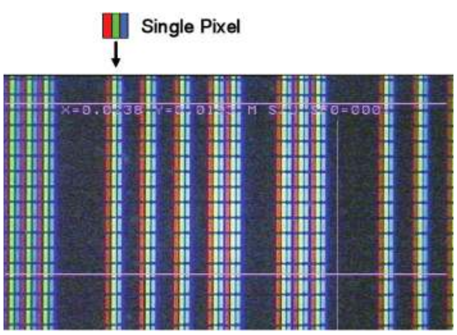


**Figure 2 - Magnified Cell Phone Display**

As is often the case with innovation, mobile bar code applications are ahead of international standards and commercial verification equipment. The lack of standards, combined with the dynamic nature of mobile bar codes displayed on an increasing variety of cell phones, present an additional burden on developers. To assure readable and robust bar codes, a comprehensive understanding of bar codes and display characteristics is required.

# 3 WHAT CAN GO WRONG?

The added flexibility and utility of mobile bar codes increase the possibility of errors that can make the bar code unreadable. In addition to the requirements of printed bar codes, factors associated with the cell phone display, such as backlighting, pixel size, and screen size must be addressed when designing and rendering the bar code. Following are some examples of problems encountered while rendering bar codes.

## 3.1 BAR CODE QUIET ZONES

In addition to the display area needed for the bar code, a "quiet zone" is required to meet bar code specifications and to promote robust reading. The quiet zone for a 1D bar code is illustrated in Figure 3. A 2D bar code requires a quiet zone along the entire perimeter of the bar code.


**Figure 3 – Bar code plus quiet zone**

The lack of a sufficient quiet zone can result in an unreadable bar code. The minimum size of the quiet zone is a function of the bar code type. For example, Code 128 requires a minimum quiet zone of 10x the module size. Larger quiet zones can increase the robustness of the bar code.

## 3.2 ELEMENT DISTORTIONS

In addition to choosing the proper bar code size and type (see Section 5), great care must be taken to ensure no distortions are introduced when the bar code is rendered on the screen. Generic software operation such as bitmap stretching, scaling, and pixel roundoff can lead to significant distortions if not performed carefully. Distortions that seem acceptable to the human eye can render a bar code unreadable. In addition, cell phone features such as image auto-rotation can produce unanticipated results.

Distortions are not limited to single pixel errors. Figure 4 shows a bar code application that produced a highly distorted 2D bar code.

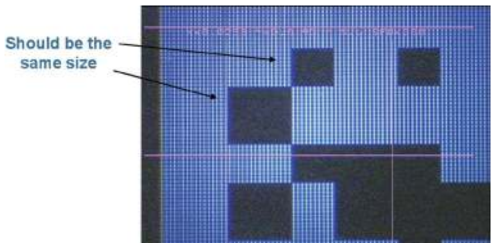


**Figure 4 - Large distortion in a 2D bar code**

Generic image viewers, such as those used for displaying email attachments, can scale, stretch, and crop the bar code image. Avoid using lossy image compression on the bar code image, such as JPEG, as it can have a profound effect on the readability of the bar code.

## 3.3 BACKLIGHT ILLUMINATION

While printed bar codes rely on an external light source for illumination, mobile bar codes are self-illuminating and rely on the backlight of the display. A mobile bar code application must assure proper backlighting required by the reader.

Phone model, user settings, display timeout settings, and ambient light conditions can affect the backlight level. Ambient light conditions can also introduce strong reflections from bright light sources, such as windows, and should be considered when locating readers. Generally the maximum backlighting is recommended when displaying bar codes.

## 3.4 READER RESOLUTION AND READING AREA

For mobile bar codes to be useful, they must be easily decodable by a bar code reader. As with printed bar codes, the bar code size and resolution must match the capabilities of the reader.

Reader characteristics include field of view (FOV), resolution, and reading range. The field of view is the area covered by the reader. The bar code must fit within the field of view in order to be read. Figure 5 illustrates an insufficient field of view. In addition, a small reading area makes it difficult to properly align the bar code with the reader.


**Figure 5 - Insufficient field of view**

The resolution of a bar code reader refers to the minimum bar code module size (i.e., minimum bar or space element within the bar code) required by the reader, while the reading range refers to the distances at which a bar code with a particular module size can be read.

Figure 6 and Table 1 illustrates a typical bar code reader's field of view and reading range.

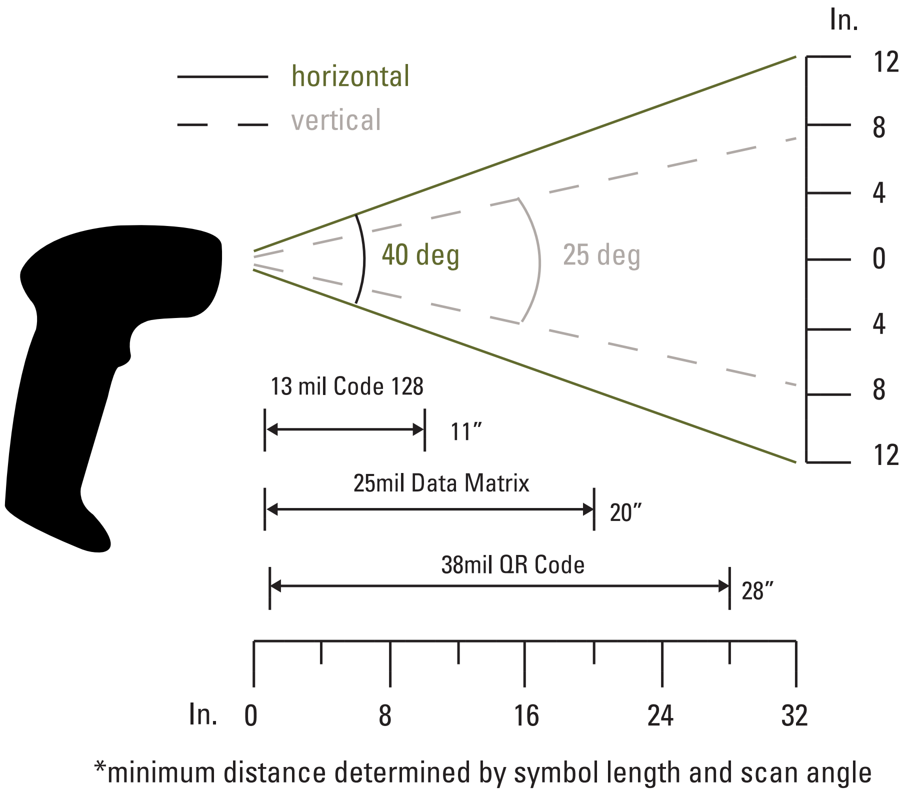


**Figure 6 - Reading range of a typical bar code reader**

| DISTANCE FORM SCANNER (INCHES) | HORIZONTAL FOV (INCHES) | VERTICAL FOV (INCHES) |
|---|---|---|
| 0 | 1.1 | 0.7 |
| 0.5 | 1.5 | 0.9 |
| 1 | 1.8 | 1.1 |
| 2 | 2.6 | 1.6 |
| 4 | 4.0 | 2.4 |
| 8 | 6.9 | 4.2 |
| `6 | 12.7 | 7.8 |
| 32 | 24.4 | 14.9 |

**Table 1 - Typical scanner field-of-view**

In general, lower density bar codes (i.e., larger module sizes) can be read at longer distances. For large bar codes, however, the near range may be limited by the field of view of the scanner. Using the previous reader specifications, a 1.5" square 25mil Data Matrix bar code will have a reading range of 2" to 20" where the near reading distance is limited by the field of view of the reader.

The reader specifications shown in Figure 6 and Table 1 are used for the bar code examples in Section 5.

## 4 DISPLAY RESOLUTION

Mobile bar code software applications must generate readable, consistent, in-spec bar codes on numerous devices and displays. Table 2 lists some common cell phones and their display characteristics.

Auto-rotation is a feature in which the cell phone's orientation automatically rotates the screen image 90 degrees, changing the aspect ratio of the display. If not properly accounted for, auto-rotation can result in distorted bar codes.

A bar code reader responds to the absolute size of the bar code elements, not the number of pixels within the elements. Therefore, it is important to keep the bar code element sizes consistent among different displays and operating modes. Generic image viewers, such as those used to view email attachments, can introduce unknown image scaling, thereby changing the bar code module size. Consistent element sizes are required for reliable and predictable reading performance.

For example, consider an application where the minimum bar code module size is 20mil. Table 3 shows the number of pixels required to meet this requirement for a variety of cell phones. To minimize bar code distortions, an integer number of pixels-per-module should be used.

| | MOTOROLA CLIQ | MOTOROLA Q | BLACKBERRY CURVE | IPHONE 3GS | NOKIA N95 | MOTOROLA DROID |
|---|---|---|---|---|---|---|
| **Screen size (inches)** | 3.1 | 2.4 | 2.5 | 3.5 | 2.6 | 3.7 |
| **Pixel size (mil)** | 5.3 | 6.0 | 6.2 | 6.1 | 6.4 | 3.8 |
| **Resolution (w x h)** | 480 x 320 | 320 x 240 | 320 x 240 | 320 x 480 | 240 x 320 | 480 x 854 |
| **Auto-rotation?** | YES | NO | YES | YES | YES | YES |

**Table 2 - Cell phone display specifications**

| CELL PHONE MODEL | PIXEL SIZE ( MILS) | PIXELS REQUIRED FOR ≥ 20MIL MODULE SIZE | RESULTING MODULE SIZE |
|---|---|---|---|
| **Motorola Cliq** | 5.3 | 4 | 21.2 |
| **Motorola DROID** | 3.8 | 6 | 22.8 |
| **Nokia N95** | 6.4 | 4 | 25.6 |

**Table 3 – pixels-per-module required for a minimum 20mil bar code module**

# 5 BAR CODE EXAMPLES

Following are examples illustrating the type of calculations useful when analyzing or designing mobile bar codes. These examples are for illustration purposes and may not be optimum for a particular application, and assume knowledge of bar code specifications.

## 5.1 1D BAR CODE

Many legacy applications (e.g., loyalty cards) use 1D bar codes. This example calculates how many digits (i.e., 0-9) can be encoded onto a Nokia N95 cell phone display with a width of 240 pixels and a pixel size of 6.4mils (see Table 2). Code 128 is a high capacity 1D bar code type suitable for this application. Table 4 shows the data capacity of a Code 128 bar code versus the total number of modules. A bar code module is defined as the smallest bar or space element in the bar code. Code 128 can contain bars and spaces of one, two, three, or four modules.

For added robustness, it is recommended that at least two pixels are used for each module. In this example, 10 digits can fit within the 240 pixel display (see Table 4). This results in a Code 128 bar code with a module size of 12.8mil and a length (including the 10x quiet zones) of 1.41 inches. Figure 7 illustrates the resulting bar code.

The reading range of this bar code can be verified using Figure 6 and Table 1. Using 13mil as a reference, the reading range is approximately 2" to 11". Note that the near range is limited by the size of the bar code and requires better alignment of the reader with the bar code due to the smaller field of view.

1D bar codes can contain a limited amount of data. If more information is needed, a 2D bar code can be used as demonstrated in the next example.


**Figure 7 – 10 digit Code 128 bar code on Nokia N95 display**

| NUMBER OF NUMERICAL DIGITS (0-9) | TOTAL MODULES (INCLUDING 10X QUIET ZONE) | REQUIRED PIXELS (2 PIXELS-PER-MODULE ) |
|---|---|---|
| 6 | 88 | 176 |
| 8 | 99 | 198 |
| 10 | 110 | 220 |
| 12 | 121 | 242 |
| 14 | 132 | 264 |

**Table 4 – Code 128 data capacity**

### 5.2 2D BAR CODE

This example calculates the data capacity of a 2D Data Matrix bar code displayed on a Nokia N95 cell phone with a display width of 240 pixels and a pixel size of 6.4mils (see Table 2). Table 5 shows the data capacity of various Data Matrix bar codes

Using two pixels-per-module (12.8mil module size), a 104 x 104 Data Matrix bar code with a capacity of 1632 numeric or 1222 alphanumeric characters can fit on a Nokia N95 display (see Table 5). A more robust bar code using four pixels-per-module results in a module size of 25.6 mils, a data capacity of 348 numeric or 259 alphanumeric characters and an overall size of 1.38 inches. This bar code is shown in Figure 8.

The reading range of this bar code can be verified using Figure 6 and Table 1. Using 25mil as a reference, the reading range is approximately 2" to 20".

Clearly, 2D bar codes are a better choice for mobile bar codes in terms of information capacity and reading range. For legacy systems requiring 1D bar codes, it may be possible to add a layer of software to translate a 2D bar code containing the required data into a format that the system understands.

### 5.3 ROBUST 2D BAR CODE

The previous examples demonstrated the practical upper data capacity that can be achieved using mobile bar codes. If smaller amounts of data are sufficient, it is highly recommended to use the additional screen area to increase the robustness of the bar code by using more pixels-per-module and higher error correction levels.

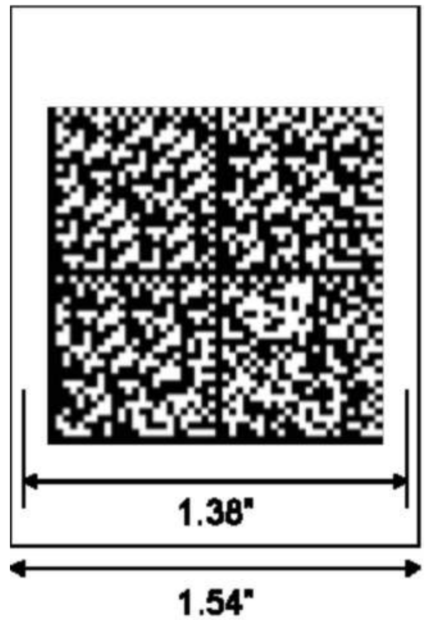


**Figure 8 - 48 x 48 Data Matrix bar code on Nokia N95 display**

Increasing the number of pixels-per-module increases the reading range while reducing the effects of pixel noise, pixel roundoff errors, and light leakage bleeding into neighboring dark pixels.

For example, consider an application where 30 numeric digits must be displayed on a Nokia N95 phone with a width of 240 pixels and a pixel size of 6.4mil.QR code is chosen for its large error correction capacity. From Table 6, a QR code size of 25 x 25 modules can store 34 numeric digits with an error correction level of 30% while using a robust six pixels-per-module.

| SYMBOL SIZE (MODULES) | SYMBOL SIZE WITH 4X QUIET ZONE | DATA CAPACITY | | REQUIRED PIXELS | |
|---|---|---|---|---|---|
| | | NUMERIC | ALPHA-NUMERIC | 2 PIXELS-PER-MODULE | 4 PIXELS-PER-MODULE |
| 48 x 48 | 52 x 52 | 348 | 259 | 104 | 208 |
| 52 x 52 | 56 x 56 | 408 | 304 | 112 | 224 |
| 104 x 104 | 108 x 108 | 1632 | 1222 | 216 | 432 |
| 120 x 120 | 124 x 124 | 2100 | 1573 | 248 | 496 |

**Table 5 - Data Matrix data capacity**

Figure 9 shows the resulting bar code which has a module size of 38.4mil and a total length of 1.19 inches. The working range of the bar code can be verified using Figure 6 and Table 1. Using 25mil as a reference, the reading range of the bar code is approximately 2” to 28”.

These examples should be considered first-order calculations, and should be confirmed through the use of prototypes and experimentation.

# 6 SUMMARY

The growing number of applications that use mobile bar codes, which are bar codes displayed on devices such as cell phones, have added a new layer of complexity to the tried-and-true bar code application. The development of mobile bar code applications requires special knowledge beyond that of printed bar code applications. This includes a detailed understanding of bar code specifications, display characteristics, reader limitations, effects of screen rendering software, and the proper choice of bar code. The use of generic image viewers, such as those used for displaying email attachments, can result in undesired scaling, stretching, and cropping of the bar code image. Care must be used to assure bar code distortions do not make the bar code unreadable.

Currently there are no public international standards for guaranteeing mobile bar code quality and readability. Until such a time, developers must take extra care to guarantee that their mobile bar codes are robust and readable on a large variety of displays.

# 7 REFERENCES

T[1] Palmer, Roger C. The Bar code Book., Trafford Publishing, 2007

[2] ISO/IEC 15415, 15416 bar code printing standards

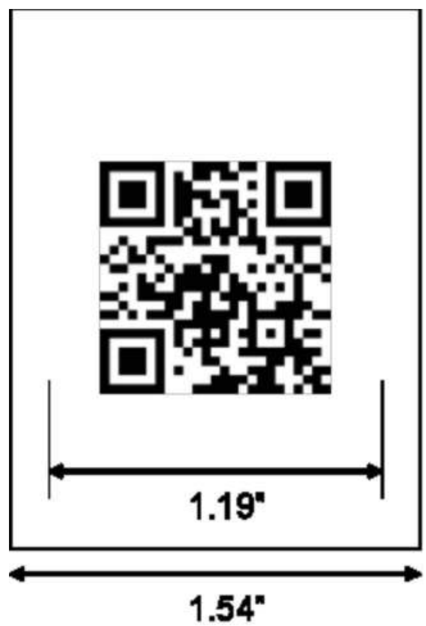


**Figure 9 – Robust QR Code on Nokia N95**

| SYMBOL SIZE (MODULES) | SYMBOL SIZE WITH 4X QUIET ZONE | ERROR CORRECTION LEVEL | CAPACITY | | REQUIRED PIXELS |
|---|---|---|---|---|---|
| | | | NUMERIC | ALPHA-NUMERIC | 6 PIXELS-PER MODULE |
| 21 x 21 | 27 x 27 | L (7 %) | 41 | 25 | 162 x 162 |
| | | M (15%) | 34 | 20 | |
| | | Q (25%) | 27 | 16 | |
| 25 x 25 | 31 x 31 | H (30%) | 17 | 10 | 186 x 186 |
| | | L (7 %) | 77 | 47 | |
| | | M (15%) | 63 | 38 | |
| | | Q (25%) | 48 | 29 | |
| | | H (30%) | 34 | 20 | |

**Table 6 - QR Code data capacity**