

MATLAB CODE FOR BPM BUTTON GEOMETRY COMPUTATION

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Abstract

Third generation Synchrotron Light Sources with vertical beam sizes down to few microns require beam resolutions on the submicron level. Study of different Beam Position Monitors (BPM) geometries has been done to reach such tight requirements. The used Matlab Graphical User Interface (GUI) is based on the simulation of a charged particle inside a selectable vacuum chamber type, computing the induced signal that it produces on the button feedthroughs. Needed parameters for the computation are the button electrode dimensions, vacuum chamber profile, electron beam current and measurement bandwidth. Output results from the GUI are the induced power on the feedthroughs, BPM sensitivity and intrinsic resolution of the analyzed geometry. As sensitivity and resolution are BPM geometry dependent terms, the Matlab GUI turned out to be an easy and fast way for first step geometry analysis.

INTRODUCTION

The idea of developing a software tool to study BPM geometries arose at the design phase of the buttons feedthrough for the ALBA machine. Non clear understanding of the best way to face the buttons design turned out to be a good excuse to spend some time developing a tool for quick analysis of different setups. Matlab mathematical software was chosen to implement a GUI based on analytical calculations from DAFNE [1,2].

WHAT FOR?

The purpose of the developed GUI is the comparison between different button feedthrough designs to determine which one better matches the accelerator requirements. As ALBA storage ring is injected from a LINAC + Booster system, two different types of vacuum chambers were thought to be analyzed. A round setup for the injector chambers and an octagonal setup for the storage ring ones. The GUI and the code behind it can be easily adapted to cope with other vacuum chamber types and geometries.

Obtained calculations for a fixed BPM geometry and different buttons designs are:

- Feedthroughs capacitance
- Non-linear BPM response
- BPM sensitivity
- Induced power on a 50Ω load
- BPM intrinsic resolution vs. beam current
- BPM intrinsic resolution vs. measurement bandwidth

understanding the intrinsic resolution as the resolution at the buttons level, not taking into account any processing electronics.

HOW TO?

Vacuum chamber

The main body of the GUI is showed in Figure 2. First thing to be done is to define the vacuum chamber geometry, quite easy for a Booster type chamber (only chamber radius is needed), but a bit more tricky for storage ring types vessels. Figure 1 shows a sketch of the dimensions required for each case.

Round type chamber are assumed to have a 45° buttons geometry, while the distance between buttons can be specified for the octagonal chamber case.

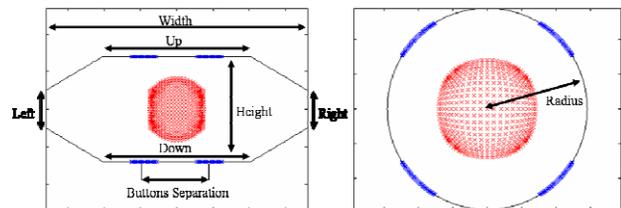


Figure 1: Vacuum chambers definition

Button feedthroughs

Code simulates the feedthroughs as round electrodes buttons type. The GUI can analyze either a single button design or make a comparison between three different buttons dimensions. Buttons are defined as:

- Electrode **diameter**
- Electrode **thickness**
- **Gap** between the electrode edge and the button shell

The button feedthrough capacitance (C_b) is obtained from these parameters and, for a specific beam current I , the average induced power is approached as

$$\langle P_0(\omega) \rangle = \frac{1}{2} |I|^2 R_0 \phi^2 \left(\frac{w_1}{w_2} \right)^2 \frac{(\omega / w_1)^2}{1 + (\omega / w_1)^2} \quad \begin{matrix} w_1 = 1 / R_0 C_b \\ w_2 = c / 2r \end{matrix} \quad (1)$$

where R_0 stands for a load impedance of 50Ω, ϕ is the coverage factor that depends on the BPM-button geometry and r is the button radius [2].

Study parameters

Detected beam signal depends on the BPM placement in the machine and therefore two different **beam current raster** can be selected. Low current thresholds are meant for BPMs installed in boosters, LINACs and transfer paths (10μA-10mA) while higher beam currents are thought for storage ring BPMs (1mA-1A).

To perform the computations, a charged particle is moved vertical and horizontally inside a ±10mm range. Broadly known *Delta over Sum* approach is used for the calculation of the position detection and BPM sensitivity.

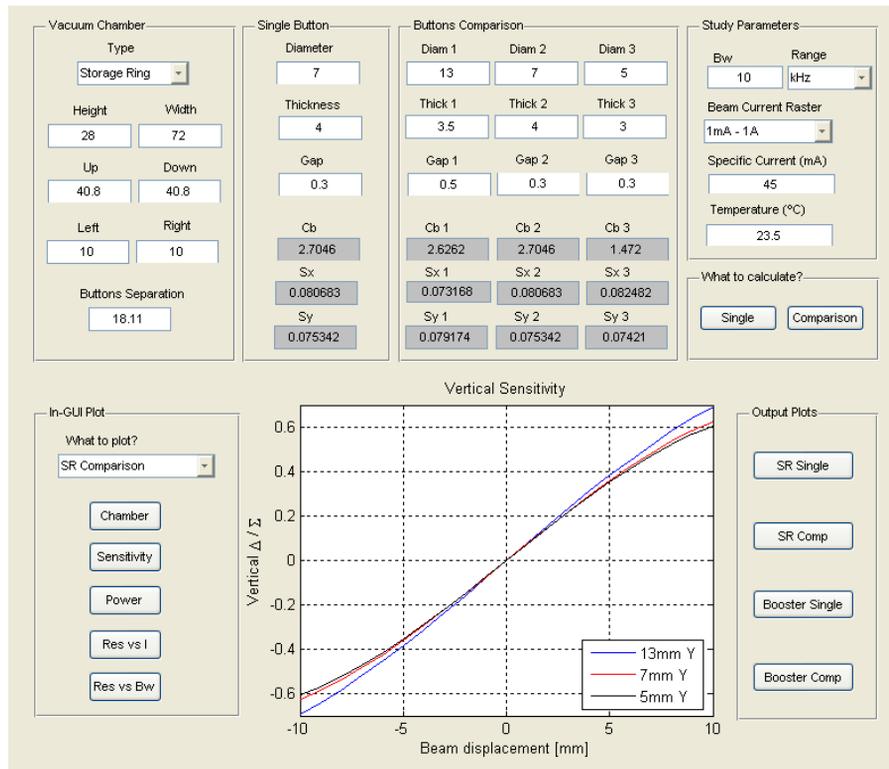


Figure 2: Matlab GUI main window. Comparison study of 3 button design is showed

The intrinsic resolution is inversely proportional to the noise level (only thermal noise considered. See equation 2). Measurement bandwidth (**Bw**) and **temperature** determine the thermal noise (N_{th}).

$$\sigma_{int} = \frac{b}{2\sqrt{2}} \frac{1}{\sqrt{SNR}} \quad b = \text{button to beam [mm]} \quad (2)$$

$$SNR = P_0 / N_{th}$$

Specific Current parameter defines a fix beam current at which the intrinsic resolution function of the measurement bandwidth is calculated.

Once the vacuum chamber geometry, buttons dimensions and study parameters are set, the computation can be performed.

OUTPUT INFORMATION

Two different types of calculations can be done: **Single** or **Comparison**. First one just computes the setup defined by the vacuum geometry and the button design set in the single button fields. Comparison study generates data evaluating all types of button designs.

First obtained information are the capacitance values of the button designs (C_b) and the sensitivity parameters of the BPM geometry S_x and S_y ($K_x=1/S_x$, $K_y=1/S_y$). For a comparison study of feedthroughs, even having the same BPM geometry, changed buttons diameters present different sensitivities.

In-GUI plots

Main GUI calculations are showed to the user as plots. All studies presented in the previous sections are

computed at the same time and can be plotted in the central GUI graph by setting the “What to plot?” controls (see Figure 3).

Chamber button generates a sketch of the BPM setup (as the ones showed in Figure 1) and illustrates the non-linear behaviour of the BPM. Red spots on the figure show the BPM sensitivity map (a square shape is ideally expected).

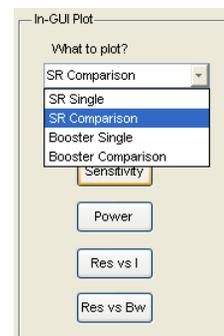


Figure 3: Selection of study to plot

The **sensitivity** plot shows the delta over sum curves function of the displaced beam, also known as calibration curves (see plot in Figure 2).

Induced power function of the beam current is showed in the central graph if **power** button is triggered. Beam current axis limits depend on the chosen thresholds in the *beam current raster* control. Figure 4 illustrates an example for a booster BPM (chamber radius 15.5mm, button diameter 14.3mm).

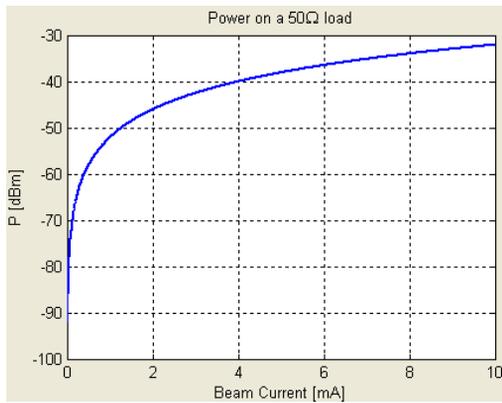


Figure 4: Induced power in a booster BPM

As can be figured out from equations 1 and 2, the intrinsic resolution of a BPM setup depends on the current of the passing beam and on the bandwidth used for measuring that beam (among other things). Therefore, two different intrinsic resolution plots are obtained. One function of the beam current, based on the analysis of the resolution on a fixed measurement bandwidth, defined by the *Bw* and *Range* controls. Second intrinsic resolution plot is measurement bandwidth dependent and is defined on a fixed beam current. Figures 5 and 6 show examples of these plots.

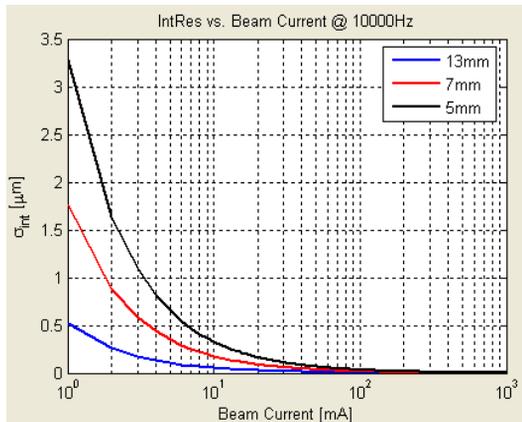


Figure 5: Intrinsic resolution vs. beam current at 10kHz measurement bandwidth

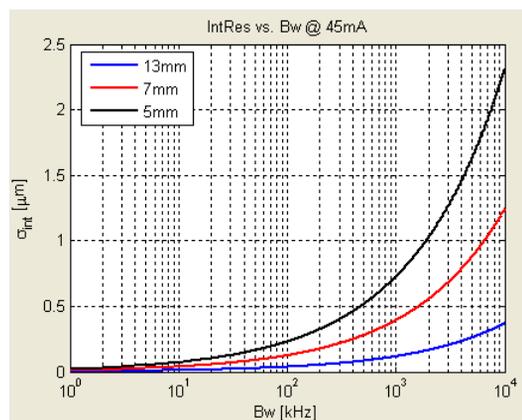


Figure 6: Intrinsic resolution vs. measurement bandwidth for a 45mA beam current

Output Plots

The control buttons grouped in the *Output Plots* box create an all-in-one independent figure that includes the obtained calculations after the computation (see Figure 7). Each different type of study (so called storage ring single, storage ring comparison, booster single and booster comparison) has its own control. These new windows give an overview of the BPM and feedthroughs behaviour.

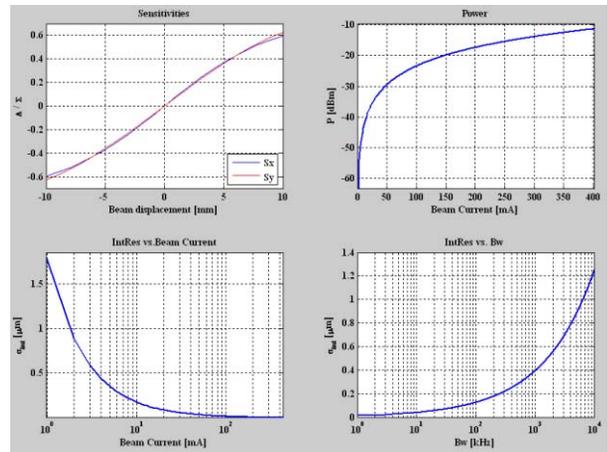


Figure 7: All-in-one output plots for the ALBA storage ring BPMs (Bw=10kHz, Specific current=45mA)

CONCLUSIONS

BPM systems main parameters are the geometry sensitivity and the resolution of position measurement, which usually have an inverse relation. Developed Matlab GUI is a useful simulation tool to look for the compromise between these parameters and help to choose the right button – BPM geometry. The results for ALBA storage ring BPM, calculated with the GUI, are showed in Figure 7 and Table 1.

Table 1: ALBA storage ring BPMs characteristics

Buttons Diameter [mm]	7
Buttons Thickness [mm]	4
Buttons Gap [mm]	0.3
Capacitance [pF]	2.7
Sx [mm⁻¹]	0.080
Sy [mm⁻¹]	0.075

REFERENCES

[1] A. Stella, “Analysis of the DAFNE Beam Position Monitor with a Boundary Element Method”, INFN-LNF, Accelerator Division, Frascati, December 1997
 [2] F. Marcellini, M. Serio, M. Zobov, “DAFNE Broad-Band Button Electrodes”, INFN-LNF, Accelerator Division, Frascati, January 1996