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# Simulation of a stripline beam position monitor of a single electrode for educational purposes.

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**Abstract.** A beam position monitor is a device used in particle accelerators which determine the position of the beam. In this work, the results obtained by computational simulation and the characterization of a stripline beam position monitor using a single electrode under the action of an electric potential are shown. The electric potential is generated along a copper cable, concentrically located on the monitor, to emulate the particle beam. The simulations were made in COMSOL®, and the response of the electric potential, on the electrode, is shown when varying the position of the copper cable on the vertical axis of the monitor. In addition, the teaching value of the device is discussed.

*Keywords:* Accelerator, particles, simulation, COMSOL®.

## 1. Introduction

Particle accelerators are instruments that use electromagnetic fields to increase the energy of the charged particles for a BPM of one pair of electrodes as shown in [1](#) or even a BPM of two pairs of electrodes. These machines produce beams of particles with specific energies and intensities that can be used in many areas, ranging from medical, industrial and scientific applications.

In the 1960s, the first particle beam position monitors were built. The importance of having this information is relevant since the path of a beam along the accelerator was unknown. The most common way to monitor the position of the charged particle beam is by coupling the BPM to the electromagnetic field. A typical arrangement for position monitors consists of a pair of electrodes or two pairs and it is common that the BPMs placed along the tube are located before and after the electromagnets (dipoles, quadrupole, etc.). Subsequently, this signal is analyzed and translated in terms of position. [\[1\]](#). Beam position measurements provide an enormous amount of diagnostic information. The access to this information can vary from periodic revisions by the operators to a data acquisition in a high bandwidth [\[2\]](#).



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*Simulation of a stripline beam position monitor.*

The main goal of this work is to simulate a single-electrode beam position monitor (BPM). To understand the concept of such a device, we can cite Peter Forck: “A beam position monitor is a non-invasive device that has a low cut-off frequency, i.e., the behavior of a direct current beam cannot be monitored” [3]. A beam position monitor will then be a device able to monitor alternate signal frequencies. The important features of a BPM are position redundancy, and temporal resolution, for example for the BPM system at the Shanghai Synchrotron Radiation Facility (SSRF) the orbit feedback system requires an information of the closed orbit of high resolution in the range of  $1 \mu\text{m}$  at a rate of approximately  $1 \text{ ms}$  [6]. There are different types of BPMs. The kind of monitor to be chosen depends heavily on the task. The most used are the stripline and radiofrequency (RF) cavity BPMs.

For this project, we focus on a stripline type beam position monitor. A BPM typically has a pair of copper electrodes or even 2 pairs of them, these pick up a voltage signal, depending on the location of the particle a current is induced at each of these electrodes. This phenomenon is known as image currents, when the particles pass through the vacuum chamber, an electromagnetic field is generated that induces a signal on the electrode in the form of a current. Therefore, a pulse extends from end to end at the electrode of length  $L$  [1].

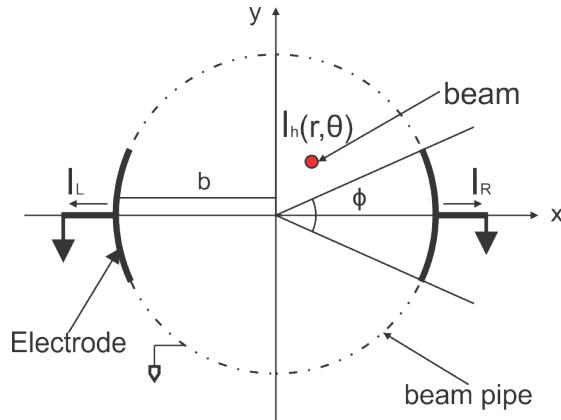


Figure 1: Stripline Beam Position Monitor.

Figure 1 shows a cross-section of a beam position monitor, the outer circular section is known as vacuum chamber, a pair of electrodes in the middle left and right is shown, usually made of copper. It also has ground terminals, where commonly at one end of the electrodes there is a load or impedance which allows us to obtain a signal reflected from it. A particle or bundle of particles following a path outside the intersection of the  $X$  and  $Y$  axis depending on the radial and angular position  $(r, \theta)$  is appreciated in Figure 1. Two electrodes (L and R for left and right) of angular width  $\phi$  are placed at 0 and 180 as shown in Figure 1.

*Simulation of a stripline beam position monitor.*

## 2. Methodology

A single-electrode stripline BPM (see Figure 2) have been built at the Science and Engineering Division of the University of Guanajuato. Simulations of this BPM geometry were performed using the software COMSOL Multiphysics®.



Figure 2: Section of a stripline beam position monitor of a single electrode.

We draw the stripline single-electrode BPM geometry using the CAD environment of COMSOL Multiphysics® as shown in Figure 3.

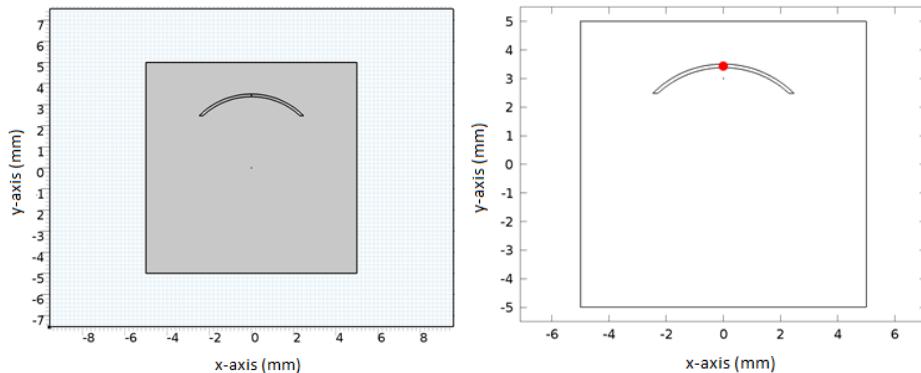


Figure 3: Left: Section of a stripline beam position monitor of an electrode in CAD design. Right: Section with a point probe to measure the electric potential at this point.

We performed 2D electrostatic simulations. We emulated the particle beam using a small charge sphere (representing the beam charge). The analyzed signal was the electrostatic potential ( $V$ ) induced by the charged sphere on the electrode a variation of the vertical distance between the sphere and the electrode top edge from 0 mm to 3 mm, in intervals of 0.5 mm was made.

If we use a cartesian coordinate system to represent the two-dimensional distribution, we will obtain a set of points known with the scatter diagram, whose analysis allows to

*Simulation of a stripline beam position monitor.*

study qualitatively the relationship between both variables as seen in Figure 4 (Right). The determination of the functional dependence between the two variables  $V$  (voltage) and  $y$  (displacement) that best fits the two-dimensional distribution is a linear regression of the form  $Y=aX+b$ . Voltage depends on the value of displacement over  $y$  axis.

Once the results of the measurements in the simulation were obtained, a equation is determined by the regression as shown in figure 4 (Left). This equation brought us information about the resulting electric potential meanwhile the position is changing.

### 3. Results

Table 1 shows the results of the electrical potential obtained by simulating a beam of particles moving from the origin  $(0,0)$  towards the copper electrode in the vertical direction.

Table 1: Data of Distance and Electric Potential.

Distance(mm)	Electric Potential(V)
0	$3.60682 \times 10^6$
0.5	$3.97706 \times 10^6$
1	$4.3472 \times 10^6$
1.5	$4.71374 \times 10^6$
2	$5.06928 \times 10^6$
2.5	$5.40403 \times 10^6$
3	$5.70847 \times 10^6$

These results were plotted to observe the behavior of the electric potential as a function of distance. In Figure 4, the values from Table 1 are plotted.

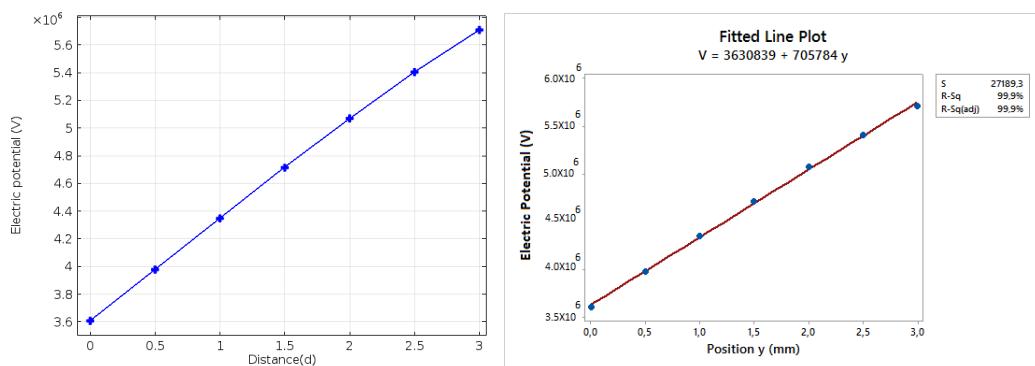


Figure 4: Rigth: COMSOL data plotted from simulation. Left: Linear regression.

Figure 5 shows the voltage influence of the simulated particle beam on the copper electrode.

*Simulation of a stripline beam position monitor.*

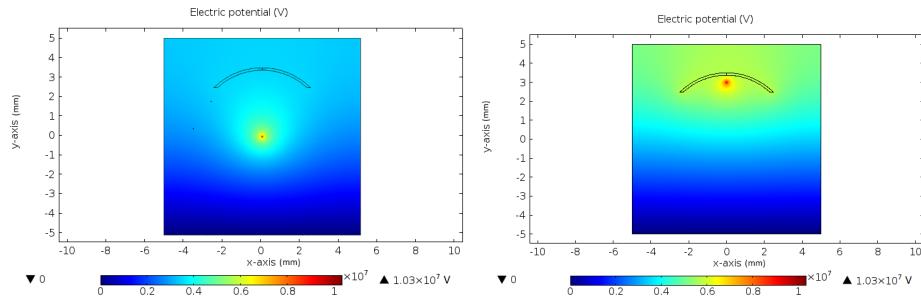


Figure 5: Image of a COMSOL simulation of the particle beam and the copper electrode [Left: At origin, Right: At (0,3) point].

#### 4. Conclusions

In this work we shown that the COMSOL 2D electrostatic simulations yield good results, corroborated by the statistical results. Moreover, the Stripline BPM being built for educational purposes can be constructed from material that is easily obtained and relatively easy manufactured at university machine-tool workshops. When the device is finished, the idea will be to compare the simulation with the measurements obtained by the device and this could be used as a training tool for students and technicians.

#### 5. Future Work:

There is intent to carry out simulations that contain more specific information, as well as to implement a system that simulates a signal that can be monitored by the electrode. In the incoming months, when the prototype and 2D electrostatic simulations are ready, we are going to simulate the 3D system with a time-varying signal instead of an electrostatic punctual charge.

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