# 3-Magnet Array – Homogeneous Spot Simulation

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# Introduction

This report describes the steps taken to produce a 3-magnet array with a homogeneous spot. To do this, the CST Microwave Studio program is used to model the magnet. Initially, the plan was to model the magnetic field of the 3-magnet array following Marble's paper on homogeneous fields of similar magnets. However, as CST Studio contains an optimization function, I felt as though it's best to make use of something that is well coded.

# Design

To construct the 3-magnet array in CST, 3 components are initially created: Case, Magnets, and Spacers. All components are set to a material of air. A list of parameters is then created to represent all lengths of the magnets. The lengths of the magnets are set based on our current inventory list of block magnets. Two spacers are included with a width to separate the center magnet from the left and right magnets. The case component contains 5 rectangular blocks that are arranged to provide the visuals for a housing around the 3-magnet array.

Once the blocks are set to the appropriate lengths, the permanent magnet feature of CST is used to set the all 3 magnets to a 'Remanent flux' of 1.44T, in the Z direction.

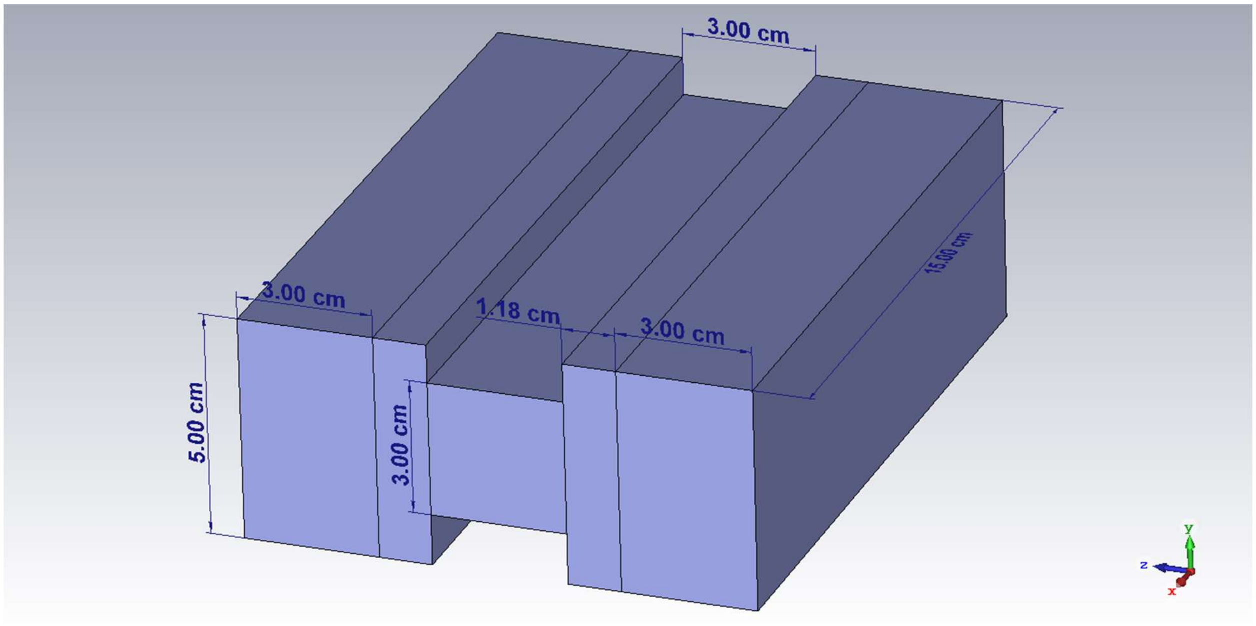


*Figure 1: 3-Magnet array diagram.*

# Simulation & Optimization

To use the CST Optimizer function, we begin by creating a 1D field plot. To do this, under 'Home', the 'Setup Solver' is set to magnetostatics with a mesh type of hexahedral, and an accuracy of 1e-12. Then by clicking 'Start Simulation', H-field and B-field results will be produced in the '2D/3D Result' navigation tree. By clicking 'Abs' in B-Field, and then '2D/3D Plot' in the top 'Results Tools' bar, we can access the 1D Field Plot option in the 'Tools' column. A 1D field plot can then be taken of the magnetic field as a function of Y.

To use the CST Optimizer, goals can be set over range within a field plot. Since we're looking for a homogeneous spot, we can take the derivative of the field plot and then iterate until the derivative is 0 over a range. Once the magnitude of magnetic field, and derivative of field plots are created, we can begin setting optimizer settings. In the 'Optimizer' window, Dip_C (center magnet dip length) is set to be a parameter with a min and max length from 0 to 3 cm. The spacer width is also set to a parameter, with a min and max length of 0 to 2 cm. The algorithm is set to

‘Trust Region Framework’, with a ‘% of initial value’ set to 0.01. The optimizer tool contains many other algorithm choices. The Trust Region Framework algorithm appears to be the best choice for this work, as other algorithms have a much longer runtime and produce equivalent results.

After inputting the initial settings, two new goals are created for the algorithm. The first, is for the derivative field plot to be equal to 0 with a weight of 1.0, from 1.5-2.5cm. Then, the magnitude field plot is set to be larger than 0.05T with a weight of 1.0, from 0-0.5 cm. Without setting this goal, the optimization software can create fields that are too weak. Once the goals are set, the optimizer is started and allowed to iterate through parameter lengths until the most optimal values are found. Below is a table describing the result of the optimization.

| | **Length (cm)** | **Width (cm)** | **Height (cm)** | **Y (cm)** |
|---|---|---|---|---|
| **Left** | 15 | 3 | 5 | 0 |
| **Center** | 15 | 3 | 3 | -0.859 |
| **Right** | 15 | 3 | 5 | 0 |
| **Spacer** | 15 | 1.177 | 5 | 0 |

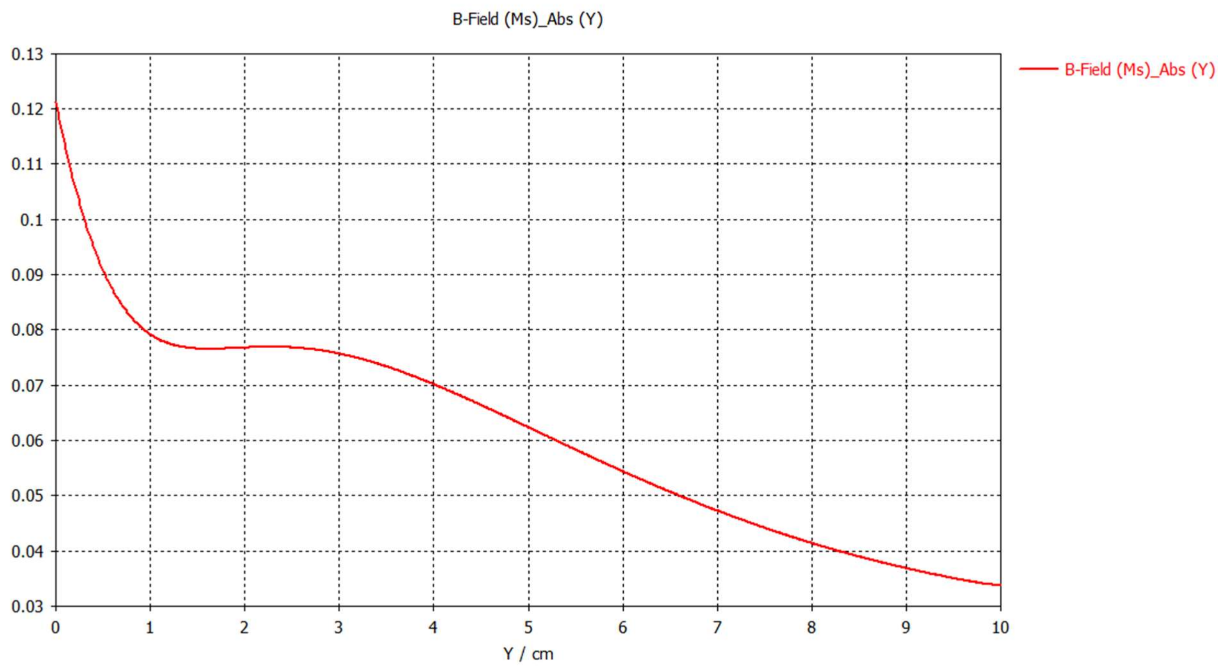


*Figure 2 : Magnitude of magnetic field (T) as a function of Y/cm produced by CST Studio.*

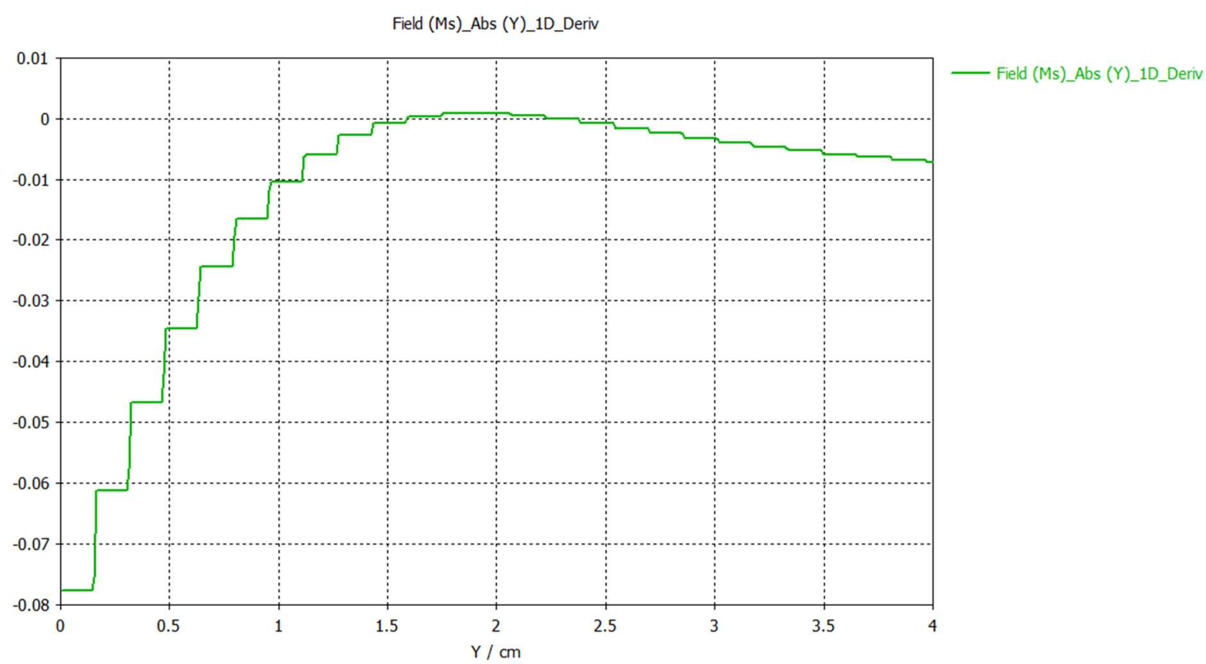


*Figure 3: Derivative of the magnitude of magnetic field as a function of Y/cm.*

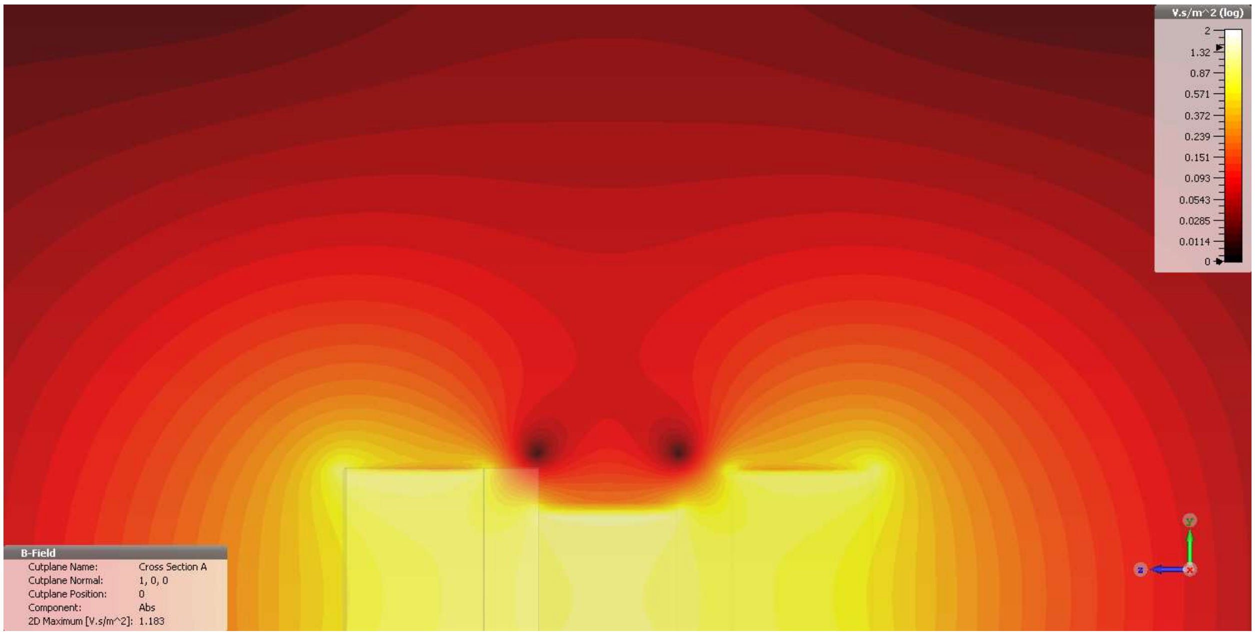


*Figure 4: Contour plot of the magnitude of magnetic field from CST Studio.*

# Conclusion

With CST Studio and the optimization tool, we've been able to create a homogeneous spot unilateral magnet. The homogeneous spot of 760 gauss (3.32MHz) exists between 1.5-2.5 cm above the surface of the magnet. There are some obvious problems with this method, if you were trying to find the most optimal result. For example, it's a bit arbitrary when setting an upper or lower bound on the parameters, if you're only searching for the largest homogeneous spot. Perhaps no limit on the width of a spacer may increase the length over which our magnet is homogeneous. However, this is not practical if we aim to have the magnet be small. For now, the bounds and goals are set such that the device is relatively small, and the magnetic field is not too weak. Some next steps could involve exploring more magnet combinations to find a larger homogeneous spot.