Name of Team: BoilerTrap
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Link: Code is at https://github.com/MRBEL-Purdue/floating-cable-trap
Live implementation can be found at https://lab.folkn.me/mri/floating-cable-trap (will be available soon)

Description:

Floating cable traps have been introduced as a variation of the traditional bazooka balun used to reduce common-mode currents in all MRI coils. The floating cable trap consists of concentric conductive cylinders that create a tuned LC tank circuit. While the floating trap is easier to fabricate, a trial-and-error approach is needed. Each iteration may require adjustments of the traps dimensions, followed by additional fabrication. To address the shortcomings of the current floating cable trap design process, we worked on developing design equations for MRI cable traps, which helps cable trap designers determine ideal trap dimensions without trial and error. We have turned these equations into a simple to use webapp and Jupyter Notebook for cable trap designers to design, generate models, and tune the cable trap via an automated design process. To our knowledge, this is the first tool that aims to simplify the process of cable traps for coil designers. This work aims to reduce the time required for optimizing the design of the cable trap by many hours.

Tool's Functionality:

We have devised the floating cable trap equation in a publication that is pending revisions. The equations yield optimized cable trap designs and tuning capacitance values, which reduces the trial-and-error time in fabrication since most cable traps geometries are not optimized and many geometries do not attenuate at the Larmor frequency.

To aid the cable trap designer with building an optimized cable trap, Python code was written to determine the combinations of optimized design parameters. The code accepts constants and constraints in the design. The program outputs a graph of possible design parameters and the most optimized result

The parametric 3D model was designed using OpenSCAD (version 2022.12.05), a scripting language based on functional programming. First, a solid cylinder with radius b (outer radius) and length l was formed. A second cylinder with radius a (inner cylinder) and length l was created, and subtracted from the first cylinder to form a hollow cylinder. Since the two half-cylinders are identical, one half of the hollow cylinder is removed by subtracting the hollow cylinder with the $x<0$ region. Finally, optional mounting holes are placed into the cylinder. The mounting holes can be placed symmetrically along the length of the cylinder or placed at user-defined locations.

The parametric nature of the 3D model means that every parameter is adjustable on-demand, with instant results. In the design process, the optimized cable trap parameters from the Python code are automatically fed into OpenSCAD for rendering. The script outputs the model as a standard stereolithography file (STL), which can be 3D printed. For further customizability, the OpenSCAD script allows the users to manually input all variables.

Cable traps manufactured using this methodology do not compromise the ability of the cable traps to attenuate common-mode currents. The parametric design methodology used in this work allows for increased consistency, manufacturing speed, and image quality (SNR) of the MRI scan while reducing fabrication costs. This work provides motivation for simplifying the design and production of other MRI hardware components.

We have tested the cable trap designer for 3 T (128 MHz), 7 T (300 MHz), and 9.4 T (400 MHz) with improved attenuation performance both on the bench and in-scanner performance.

Our tool can be used to generate floating cable traps for all vendors and all magnetic field strengths. The tool can design cable traps for transmit and receive coils, intervention equipment, and emerging technologies such as wireless power transmission in MRI – it is only limited to the imagination.

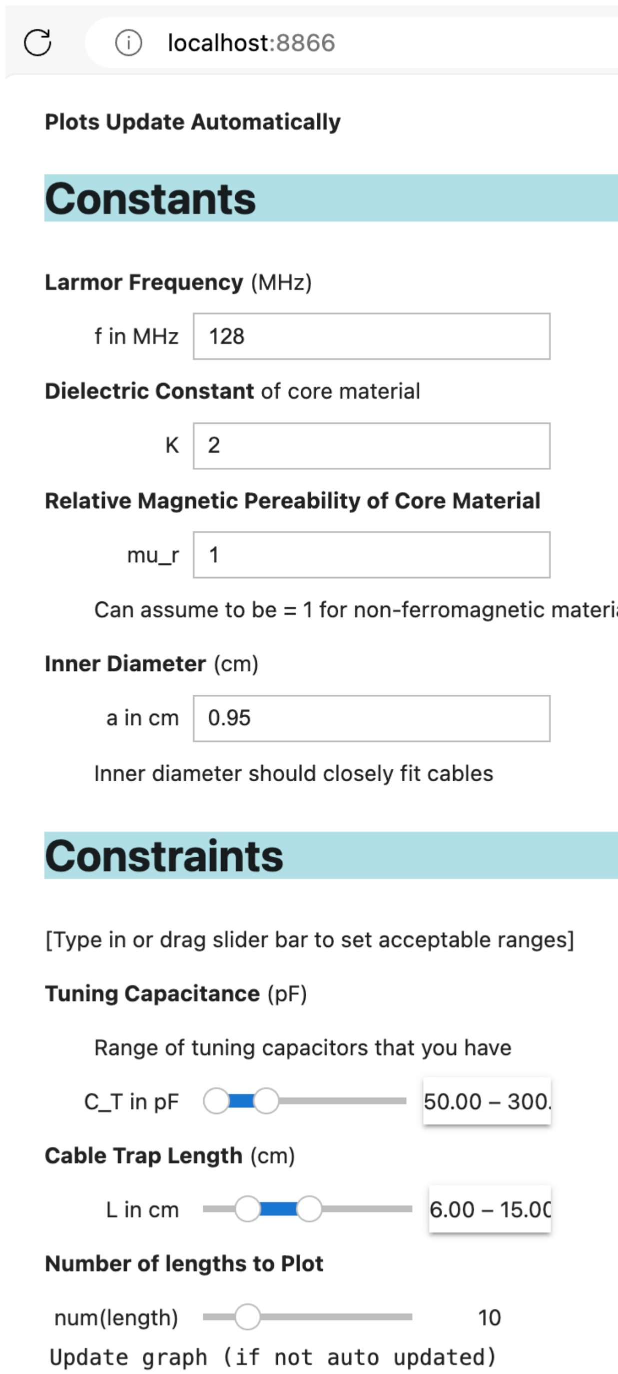

Figure 1: Example of the web-application to design the cable trap

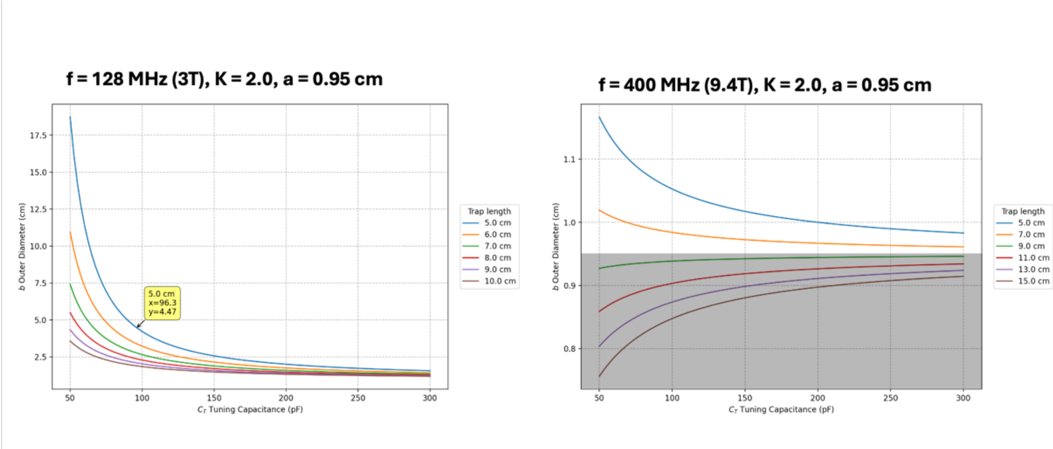

Figure 2: Example Results as an interactive plot from the code. The arrow (left) points to the most optimized cable trap. (Left) 3T, (Right) 9.4 T. The shaded area represents infeasible or impossible designs

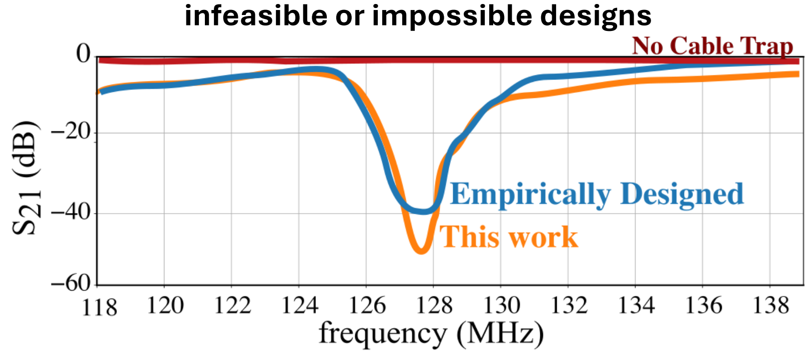

Figure 3: Improvements to the coaxial shield attenuation performance designed using our software versus when empirically designed

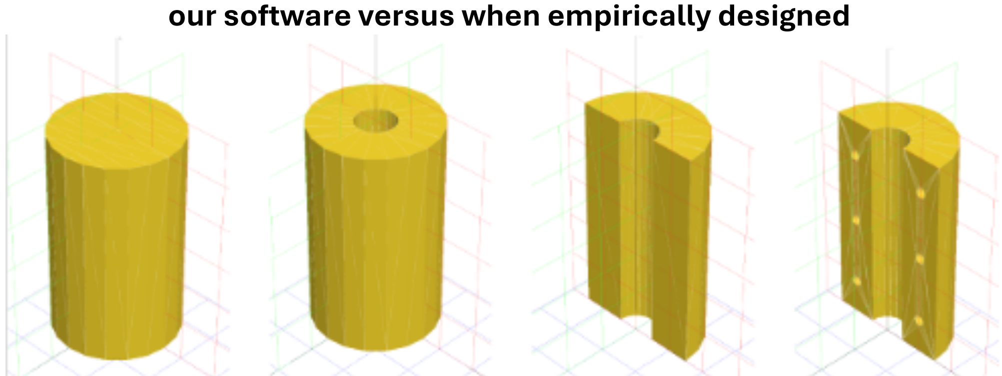

Figure 4: Process that the code uses to generate a 3D model of the cable trap based on optimized parameters.