

Goal:

- Compute a matrix of admittances Y for given multilayer superconductive layout and a set of locations (*terminals*) where phase drop between metal layers can be specified.

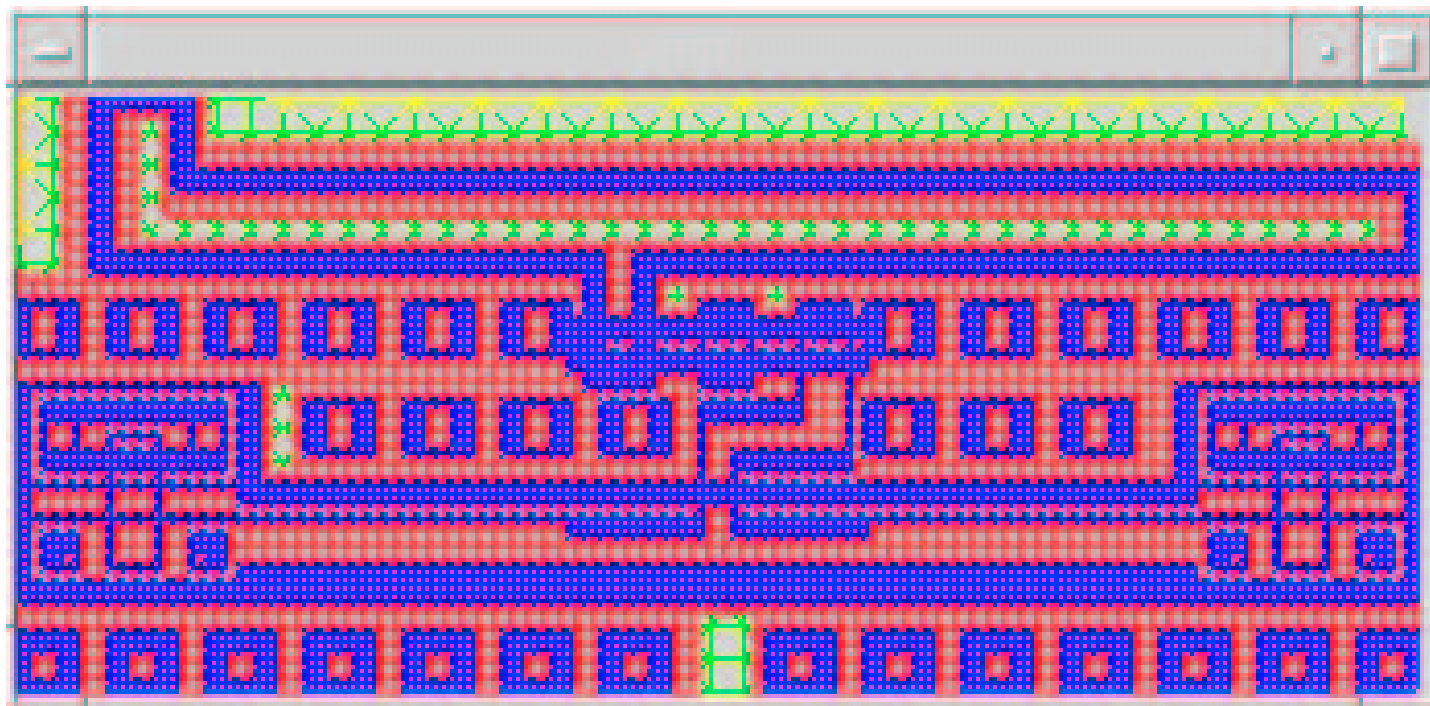
$$I = Y \cdot \Phi$$

I is a vector of currents through all terminals

Φ is a vector of phase drops on them.

- **LMeter** models an *experiment* in which phases are applied across terminals and currents are measured.

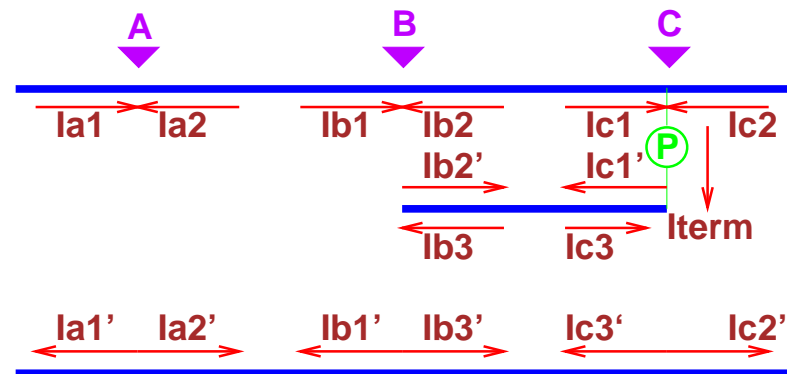
Finite Element grid generated by LMeter



Step 1:

- Write current continuity equation:

$$\sum_{\text{All directions}} \text{Current flowing in this direction} = 0$$



$I = I'$ for all currents
(reflection principle)

$$I_{a1} + I_{a2} = 0$$

$$I_{b1} + I_{b2} = 0$$

$$I_{c1} + I_{c2} = I_{term}$$

$$I_{b1} + I_{b3} = 0$$

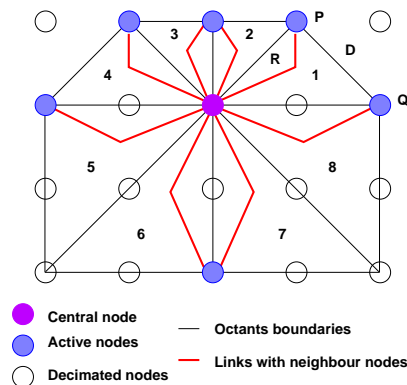
$$I_{c3} + I_{c2} = 0$$

Step 2:

- Write out currents in terms of phase differences between the superconductive layers and isolator thicknesses.

$$\frac{1}{d_{mag}} \int_P^Q \frac{\phi(x) - \phi(0)}{r(x)} \approx \frac{1}{d_{mag}} \frac{D}{R} (\phi(P) - \phi(0))$$

$$d_{mag} = \mu_0 \cdot (d + \lambda_1 \coth(\frac{t_1}{\lambda_1}) + \lambda_2 \coth(\frac{t_2}{\lambda_2}))$$



Step 3:

- Write out phase differences in terms of basic variables — phase differences between *consecutive* independent electrodes and known values — phase drops on the terminals.
- Move known values to the RHS.
- Solve the resulting positive semidefinite symmetric system of linear equations with different right-hand sides using conjugate-gradient methods with incomplete Cholesky factorization.

Taking into account 3D effects and fabrication shifts:

- Boundary inductance approach:

$$L_{3D} = L_{edge} || L_{2D} || L_{edge}, \quad L_{edge} = \frac{1/2}{\frac{1}{L_{3D}} - \frac{1}{L_{2D}}}$$

- Advantage — L_{edge} has much weaker dependence of W and d_{mag} than fringe factor.

- Modification in the program:

$$\frac{1}{d_{mag}} \rightarrow \frac{1}{d_{mag}} \cdot \left(1 - \frac{s + \lambda}{R/2}\right) + \frac{1}{L_{edge} \cdot R/2}$$

Conclusions:

- **LMeter** can take into account 3D effects and fabrication shifts with accuracy better than 5%.
- **LMeter** was successfully ported to and is now in use in several operating environments, including Linux on IBM PC, IRIX on SGI's Indy and HP-UX on HP's PA-715.
- **LMeter** can import layout description from several CAD systems, including Autodesk's AutoCAD, Cadence's layout-Plus and all CAD systems that can export files in CIF format.
- Problems of more than 100,000 degrees of freedom were solved using **LMeter** . In usual **LMeter** 's run more than 60,000 equations are generated and solved in several minutes on SGI's Indy.