Lab 3. Capacitance Matrix Solution Using Maxwell 2D Extractor

Name: ____________________________  Date: ____________________________

1 Introduction

In this lab, the Maxwell 2D Extractor from Ansoft is used to calculate the capacitance of two-dimensional structures. The purpose of the lab is to learn to use the commercial electromagnetic software and to gain insight into the physical meaning of the capacitance.

The Maxwell 2D Extractor is an interactive software package that can be used to electrically characterize two-dimensional structures such as transmission lines, cross sections of connectors, and so forth, where the field patterns in the entire device can be analyzed by modeling the field patterns in its cross section.

In the Maxwell 2D Extractor, you specify the parameters to compute, draw a cross section of the transmission line structure, and specify relevant material characteristics, conductor types, and boundary conditions. After you finish, the Maxwell 2D Extractor is able to:

1. Compute the capacitance and inductance for the 2D structures
2. Display field patterns that would exist in the structure given a particular distribution of charge, potential, or current
3. Export a SPICE equivalent circuit to a file that can be read into other software packages

2 Problem

Fig. 1 shows the cross section of two signal conductors on the substrate. The capacitance between conductor 1 and the ground plane is the self capacitance $C_1$. The capacitance between conductor 2 and the ground plane is $C_2$. The capacitance between conductor 1 and conductor 2 is the mutual capacitance $C_3$. The capacitance matrix solved by Maxwell 2D Extractor is

![Figure 1](image-url)
Figure 2:

\[
C = \begin{bmatrix}
  C_1 + C_3 & -C_3 \\
  -C_3 & C_3 + C_2
\end{bmatrix}
\]

Due to the mutual capacitive coupling, when there is a transient signal on one conductor, noise will be induced on the adjacent conductor. The coupling coefficient is defined as

\[
K_C = \frac{C_3}{\sqrt{C_1 * C_2}}
\]

A third conductor can be added between the two conductors to reduce the coupling. It is called the guard trace. We are going to use Maxwell 2D Extractor to compute the capacitance matrix and coupling coef. of the three cases shown in Fig. 2 and then analyze the effect of the guard trace.

3 Getting Started

1. Go to the class web page, read through the tutorial (TL2DGSG.pdf).

2. Copy the start up project \texttt{3start} from \texttt{n:/Maxwell/} to \texttt{c:/Project/Lab3/}. Open the project from Maxwell 2D Extractor (refer to Chap. 2 and Chap. 3 in the tutorial). \textit{Be sure that the project you have opened is the copy you made on c: not the original one on n:}. You should see a window shown in Figure 3. If it says ”the project is locked” and you cannot open it, copy the project to a new one by clicking the button \texttt{copy...} in Maxwell Projects.

The two small red rectangulars are two signal conductors named as \textit{left} and \textit{right}. The blue layer is the substrate. The thin white layer is the ground plane called \textit{ground}. This is the case in Fig. 2(a). We can get started from this sample project.

3. Set up the problem. Refer to Chap. 5 in the tutorial for the detailed instruction.

   - Setup Conductors (Refer to 5-2).
     Set \textit{left} and \textit{right} to signal-carrying conductors. The capacitance parameters are computed for signal conductors only. Define the ground plane \textit{ground} as an ideal grounded conductor. Leave the \textit{substrate} alone.

   - Setup Materials (Refer to 5-5).
     Assign the background as vacuum. Assign the \textit{ground}, \textit{left} and \textit{right} as copper. And assign \textit{substrate} as the material \textit{FR4-epoxy}.

   - Setup Boundaries/Sources (Refer to 5-9).
     Choose \textit{Setup Boundaries/Source/Use Defaults}.  

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**Note:** The image contains a diagram showing the arrangement of signal conductors and a guard trace with labels for left, mid, and right segments. The text explains the mathematical derivation for the coupling coefficient and outlines the steps for setting up a project in Maxwell 2D Extractor. Key steps include copying the project, defining conductors, and assigning materials and boundaries. The tutorial recommends reading through the tutorial document for detailed instructions.
4. Generate a Solution. (Refer to 6-8).
   Choose Solve Parameters. The menu of solving parameter appears. Choose capacitance.
   After the Extractor has obtained the solutions, you will be able to view the capacitance
   matrix by choosing Solutions/Capacitance.

5. Analyze the solution. (Refer to Chap. 7 in the tutorial).
   Choose View Fields/Capacitance. A view of the problem region appears. Then choose
   Post/Plot. Leave the Voltage under Value set to Yes. Better Hardcopy set to No. Then
   the simulator plots the equipotential contours.

6. Print out the equipotential contours.
   Go to the Ansoft control panel (shown in the upper graph on 2-2). Press the icon
   PRINT. The print window pops up. Choose Grab screen. Then use mouse to select
   the part of graph you want. After you are done with the selection. The selected part
   of graph appears in the print window. Save it as “potential.bmp”. Choose File/Print
   and print the graph. Don’t forget to write down its title on the sheet.

4 Adding Guard Trace

We then put a guard trace midway between left and right conductors and see what kind of
effect it has on the capacitive coupling. Two cases are to be tried. One is to set the guard
trace mid as a floating conductor. The other is to ground the guard trace.

1. (a) Make a copy of the first project. Go to the Project Manager window. Click on
   copy.... Copy the project you already have l3Start to l3Float. Select model only
   option in copying.
   (b) Now open l3Float. Choose Draw Cross Sections.... We are going to copy a rectan-
   gule to create mid. Strictly follow the following instructions.
• Left click on left to select the rectangle. Make sure it is the only object being selected.
• Choose Edit/Duplicate/Along Line... . Then two fields U and V, which are the x, y coordinates of the anchor point appear at the bottom of the screen. Press Tab key once, enter “-2” in the field U and “0” in the field V and then hit return. After that, four fields U, V, dU and dV are shown which specify the target point. Enter “1” for U and “0” for V and hit return. Enter “2” in the popped up dialog box. A new rectangular object is copied between left and right.
• Make sure the new object is the only one being selected. Choose Edit/Attributes/Rename... . Rename the new object from left1 to mid.
• Save the changes and exit.

(c) Still we need to go through the steps of setting up conductors, materials and boundary conditions described in 3.3 to 3.6. Here set mid as floating conductor.

(d) Solve the capacitance matrix.

(e) Print the equipotential contour.

2. (a) Go back to Project Manager. Copy the project b3_float to a new project b3_ground. Open the project b3_ground. Go through the steps described in 3.3 to 3.6. This time set mid as an ideal ground conductor. You cannot directly assign two objects as ideal ground. Next step describes how to do it.

(b) Choose setup conductors... Choose multiple select. Select the objects ground and mid at the same time. Choose group which is under the Object list. Name the group as GND. Assign GND as ideal ground. When you assign ideal ground to this group, both objects in the group are assigned as ideal ground.

(c) Solve the capacitance matrix.

(d) Print the equipotential contour.

5 Things to turn in

The capacitance matrices and the equipotential contours for all three cases. Be sure to write down the titles of the graphs.

Answer the following questions:

1. Find the coupling coefficients of all three cases.

2. Explain the changes in coupling coefficients by inserting the middle conductor and by inserting a grounded middle conductor.