



## The Design of 2.4GHz LTCC Band-Pass Filters with Enhanced Stop-Band Characteristics

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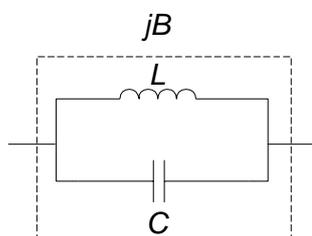
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### Introduction

Nowadays, the development of CAD tools in assisting circuit design is of great importance for increasingly complex structures. In this application notes, the design of a 2.4GHz Band-pass filters implemented by the Low Temperature Co-Fired Ceramic (LTCC) technology is introduced. To facilitate this LTCC design, an electronic design automation (EDA) tool, **Advanced Design System (ADS)**, developed by **Agilent Eesof** is applied here.

### Theory

Realization of the transfer functions of passive band-pass filters in practice is a challenging work. The transfer characteristic should offer a sufficient attenuation in the stop-band, while providing a flat pass-band with small insertion loss. One of the options to enhance the stop-band characteristic is by the insertion of transmission zero. Fig. 1 illustrates the structure for the realization of transmission zeros such that:



$$B = 0 \text{ for } \omega = \omega_z$$

where B is the susceptance of the L - C resonant tank

$\omega_z$  is the frequency at which the transmission zero located

Fig. 1 Structure for the Realization of Transmission Zeros

By introducing such characteristic into a standard band-pass filter prototype, the stop-band characteristic of the filter can be improved. Fig. 2 depicts a second-order Butterworth filter after the introduction of the characteristic shown in Fig. 1. Based on the design specifications, all the circuit elements in the filter can be evaluated explicitly by the design equations. For verification, the schematic as well as the physical layout of this filter are simulated by **ADS**, which are illustrated in the following sections.

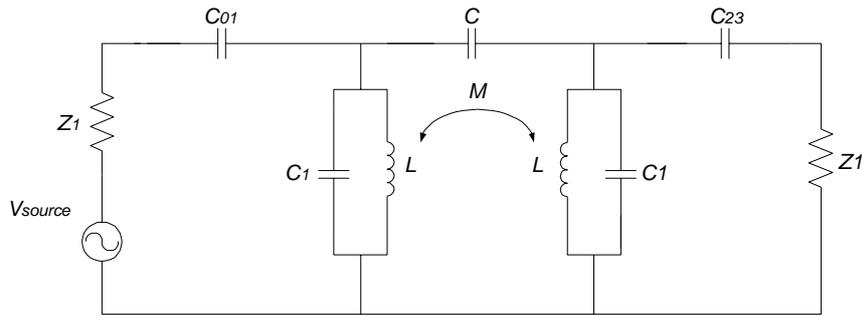


Fig. 2 A Band-Pass Filter Structure with Improved Stop-Band Characteristic

## Schematic Simulation

### 1. S-parameter Simulator

Various simulators are available in **ADS** for specific purposes. For filter designs, **S-parameter simulator** is usually applied. By selecting this simulator, circuit characteristics, such as S-parameters, group delay and linear noise can be obtained. Y- and Z-parameters can also be found by the transformation from the s-parameters. Before simulation, some parameters have to be pre-defined (Fig. 3), including the range of frequency under consideration (**Start** and **Stop**) and the number of points to be simulated (**Num. of pts**).

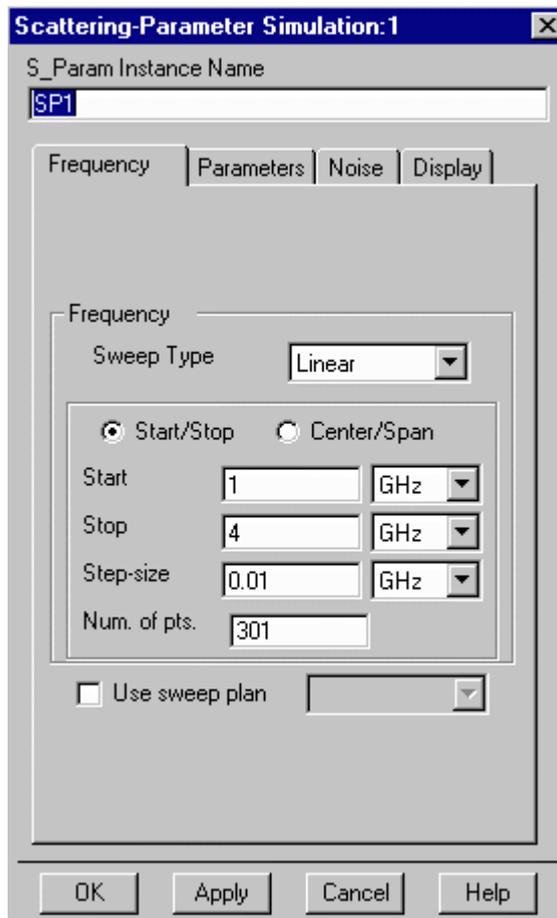


Fig. 3 Parameter Setting for S-parameter Simulation

### 2. Drawing of Schematic

The components can be either inserted from the **component library window** or from the **component palette** appearing on the left-handed side of the **schematic window** (Fig. 4). The **s-parameter ports** and the **simulation setup box** are the essential elements for the s-parameter simulation. Fig. 4 illustrates a circuit ready for simulation.

### 3. Schematic Simulation

Once the circuit simulation is started, a **simulation window** showing the simulation time and running status appears on the screen (Fig. 5). The generated data is stored in a **Dataset**, which can be displayed in the **Data Display Window**. In **ADS**, it is possible to display the data in various formats, such as linear plot, polar plot and smith chart. For clear illustration, markers can be inserted to the plots. To undergo further computation on the data, mathematical equations can be inputted as well. Fig. 6 illustrated the simulated frequency responses of the filter (Fig. 4) with markers inserted at the resonant point (2.4 GHz)

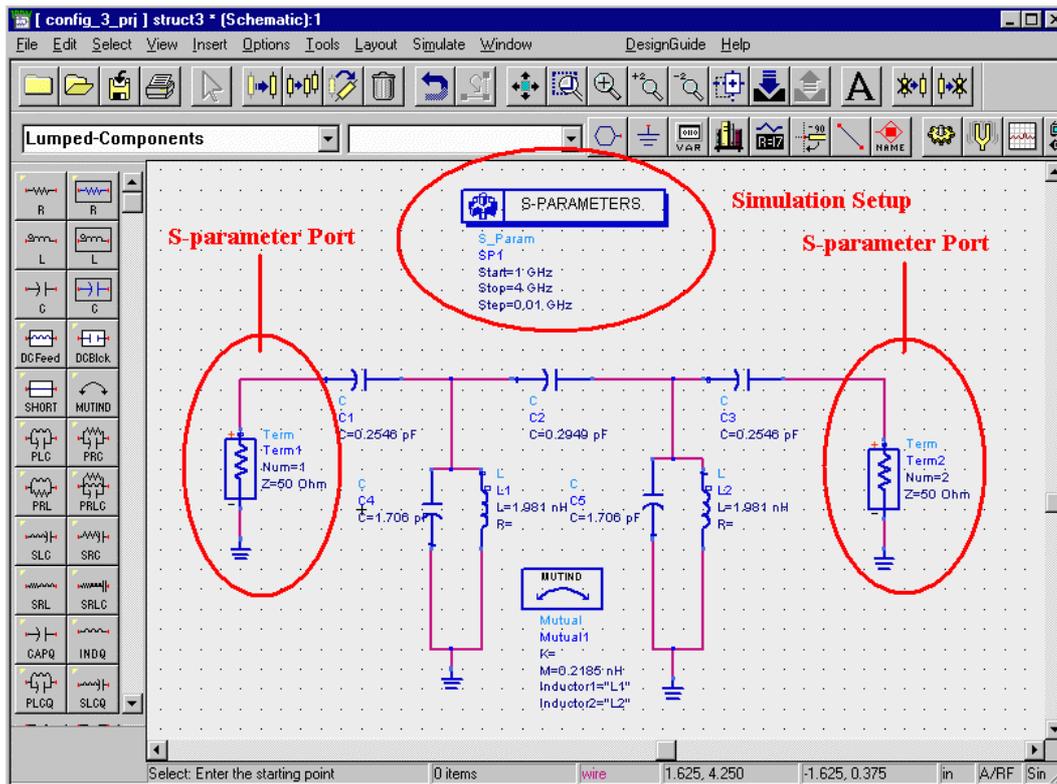


Fig. 4 Schematic Window in ADS

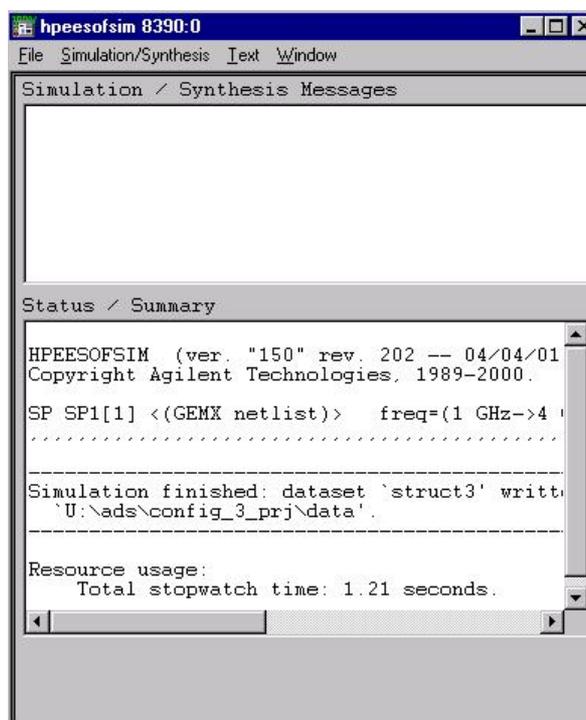


Fig. 5 Simulation Window in ADS

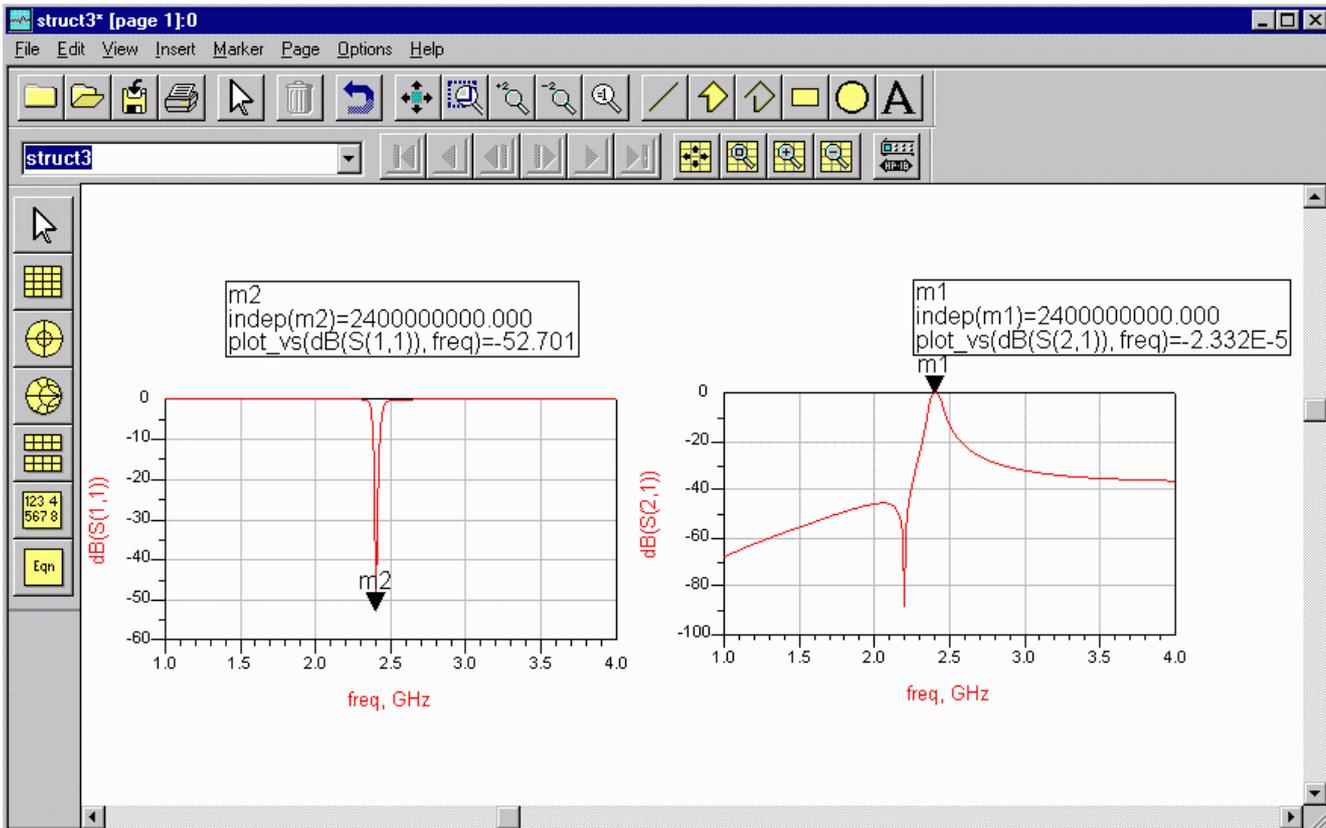


Fig. 6 Data Display Window in ADS

## Layout Simulation

### 1. Momentum

After the schematic simulation, the schematic can be transformed into layout. For examples, capacitors can be realized by simple parallel plates or multi-layer structures. On the other hand, inductors can be realized in the forms of spiral or rectangular strip. Since the LTCC band-pass filter going to be designed is of multi-layer structure with passive components embedded inside, **Momentum** provided in **ADS** can be applied here for layout simulation. **Momentum** is an electromagnetic simulator for simulations on passive and planar circuits.

### 2. Drawing of Physical Layout

There are three ways to prepare a physical layout in **Momentum**: 1) Convert from a schematic, 2) Draw directly in the **Layout Window** and 3) Import from another design system. In **Momentum**, various common file formats, such as DXF and GDSII can be imported. The finalized layout is shown in the **Layout Window** (Fig. 7). As illustrated in the figure, different colours refer to the conductive materials in different layers.

Before layout simulation, all the material properties in the layout have to be pre-defined. The settings for the substrate and metallization layers are illustrated, respectively, in Fig. 8 and Fig. 9.

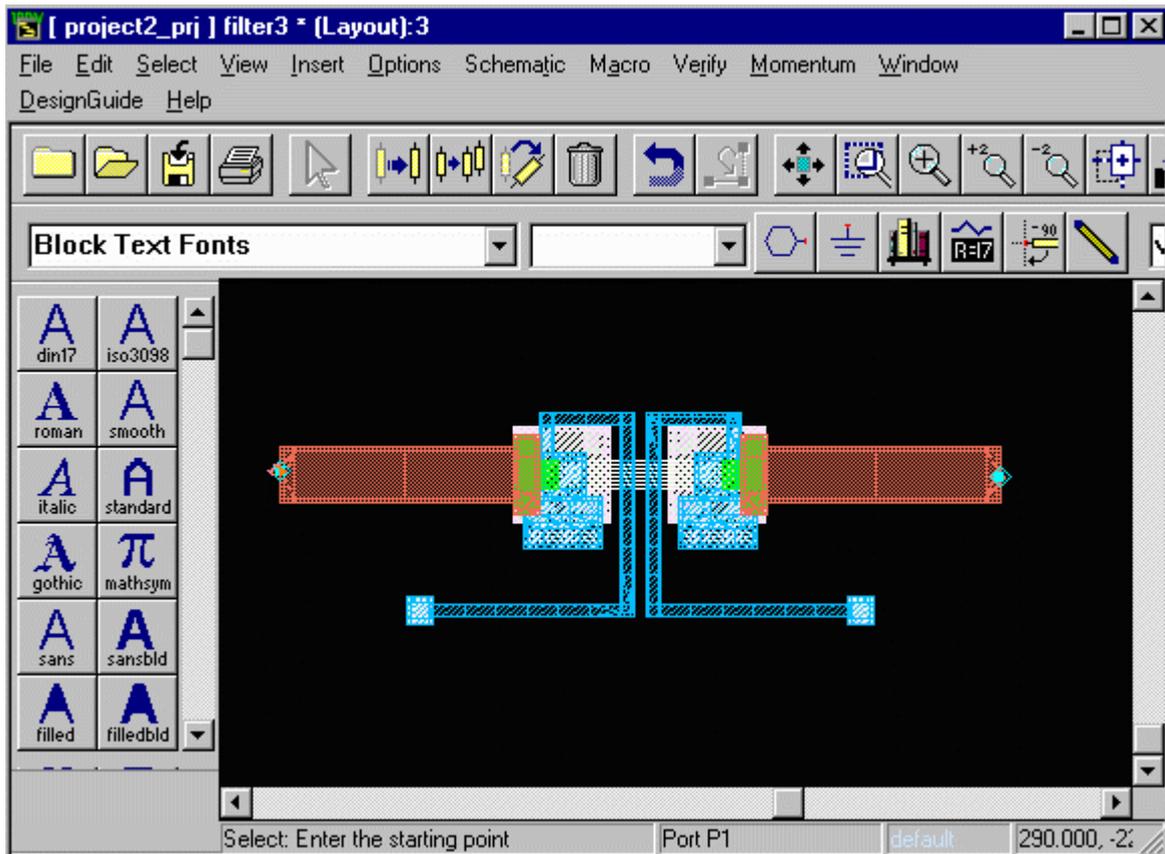


Fig. 7 Finalized Layout in the Layout Window

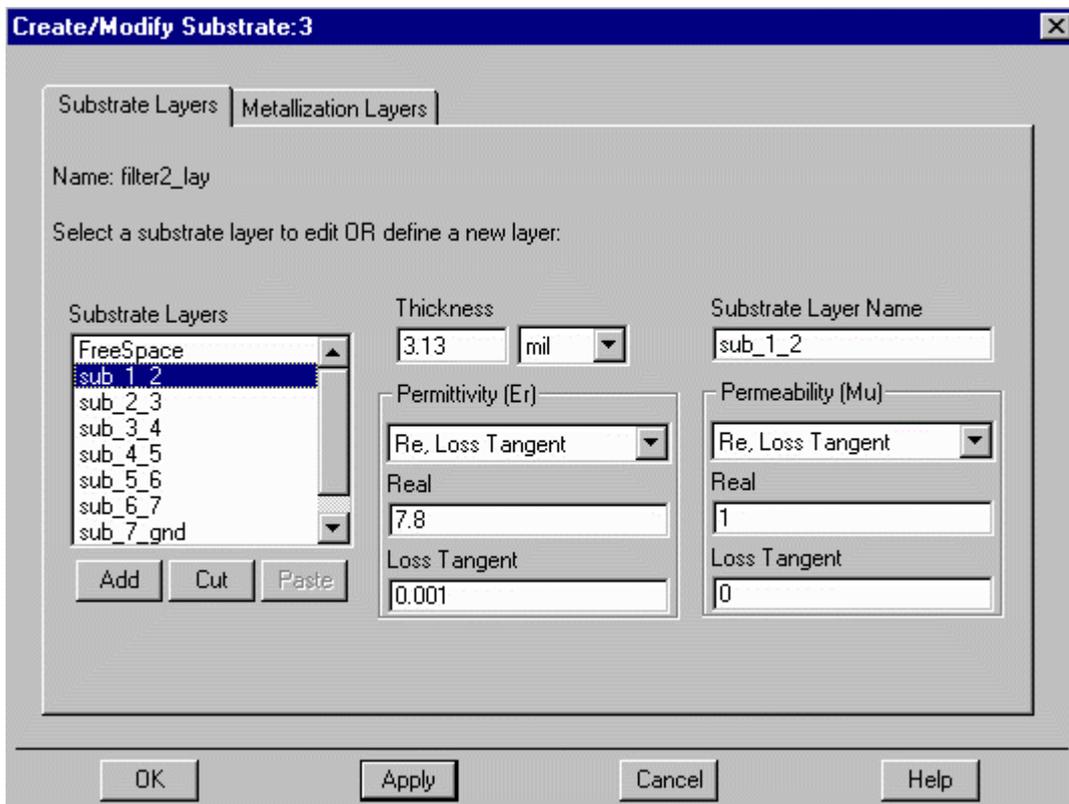


Fig. 8 Definition for the Substrate Layer Characteristic

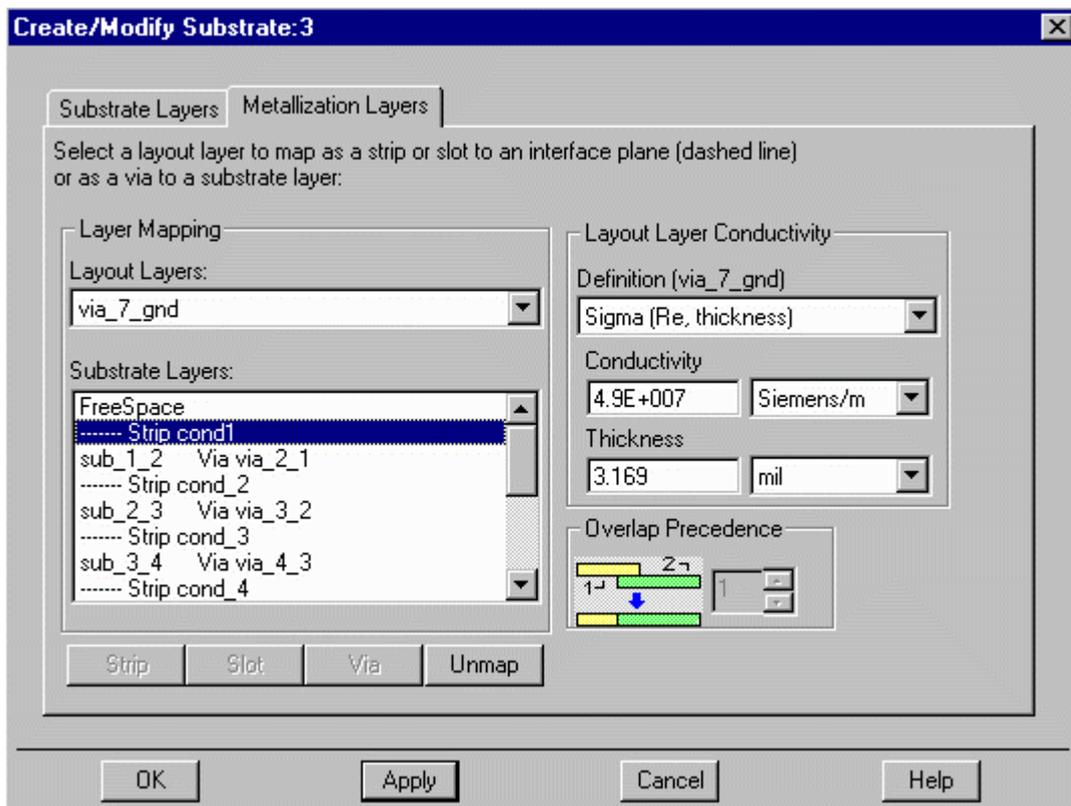


Fig. 9 Definition for the Metallization Layer Characteristic

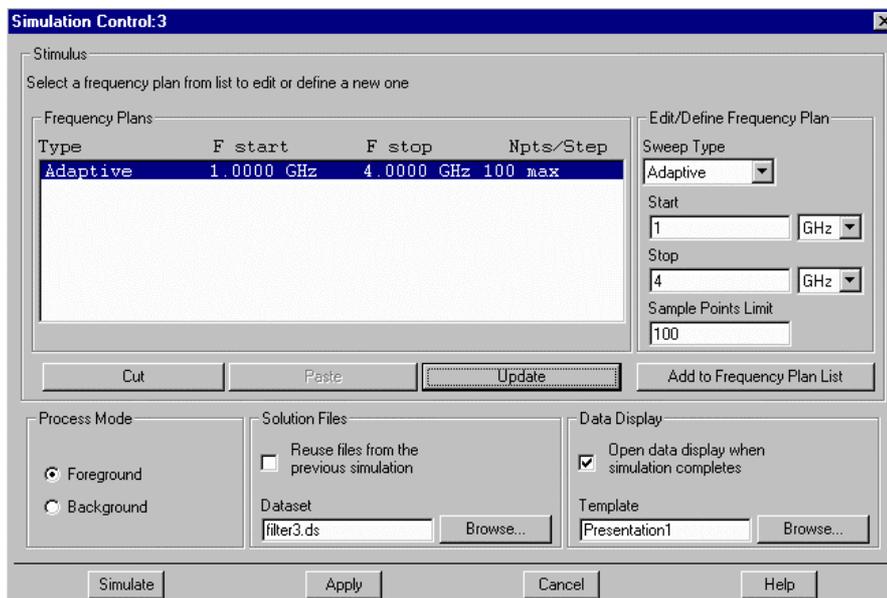


Fig. 10 Frequency Plan for Layout Simulation

### 3. Layout Simulation

Similar to the schematic simulation described previously, a **frequency plan** has to be set before the simulation starts (Fig. 10). The main parameters in the plan include the **sweep type**, **start** and **stop** frequency as well as the **sample points limit** under consideration. After invoking the simulator, a **Simulation Window** (similar to Fig. 5) showing the simulation progress and the error messages (if any) during the

simulation is invoked. The simulated data is stored in a **Dataset**, which can be displayed in the **Data Display window** (similar to Fig. 6). Note that a 3D view (Fig. 11) of the physical layout at different angle and scale can be attained as well.

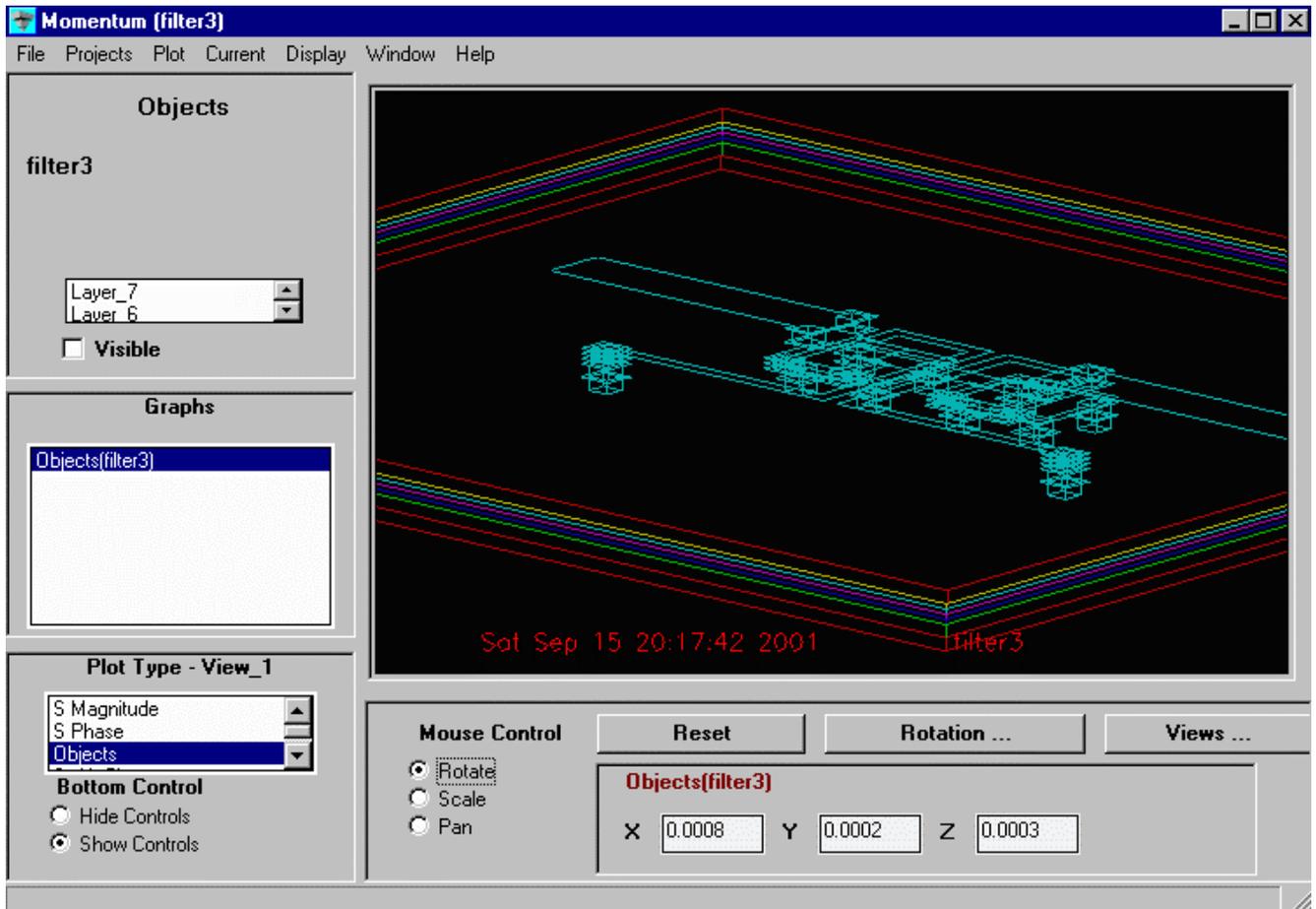


Fig. 11 3D View for the Finalized Layout

## Conclusion

To facilitate LTCC circuit design, various types of CAD tools are required. **ADS** is one of the options. One of the important features in **ADS** is related to the feasibility in the linkages to many third-party softwares, which is considered to be a convenience for the circuit designers.