Wireless Circuits and Systems Laboratory

Procedure #5 Using the Linecalc Program in ADS

Linecalc is a program contained within the ADS suite that can be used to analyze a wide variety of different transmission line types. For example, with microstrip, you can specify the substrate parameters (primarily thickness and dielectric constant) and use Linecalc to calculate the impedance for a given line width; this is the "analysis" mode. You can also specify the substrate and the characteristic impedance, and have Linecalc determine the necessary line width; this is the "synthesis" mode. The techniques used in Linecalc are flexible and accurate, taking into account metal thickness, conductivity, frequency dependence, etc.

The procedure outlined below explains how to use Linecalc for analyzing microstrip, and also for analyzing "coupled" microstrip lines (two strips which are in close proximity).

Linecalc is started from within a **circuit schematic** window, by clicking on the Tools button in the top menu row.

Word of caution: You may find Linecalc behaving somewhat stubbornly during your simulations. For example, it may continue to reset the frequency to an undesired value after you try to change the frequency and then re-analyze or re-synthesize. Or, it may not allow you to change to a certain unit measure of length (microns, mm, etc.) This type of situation is usually a result of transmission line parameters (physical or electrical) becoming either too small or too large for the current units/precision you are using.

1. Using Linecalc to Characterize Microstrip Transmission Lines

After successfully starting Linecalc:

1. The first thing you may want to do is save your Linecalc simulation: click on File>Save As and change directories to your project directory (you may also want to go into your Networks directory to save the file). We will call this file micro-1.lcs, for the purpose of demonstration. At a later date, you can open this file within Linecalc and modify the parameters as necessary.

2. Select the frequency to a value that lies approximately in the center of the band that you are interested in; for this example we will choose 1.5 Ghz. Frequency is found in the Component Parameters in the lower left-hand side of the window.

3. Now we will specify the type of transmission line. In the Component Type window, click on the Select... button. Scroll down the list of element types until you come to MLIN (which stands for microstrip line), select this and click the Apply button and then OK.

4. Now we will specify the substrate. We will assume we are using a fiberglass-based FR4 board with a dielectric constant (**Er**) of 4.3 and a thickness (**H**) of 1.57 mm. The metal thickness (**T**) is 0.043 mm and the dielectric loss tangent (**TanD**) is 0.022. You will find each of these parameters in the Substrate Parameters window. Make sure you correctly specify the units. [The remaining parameters should be: relative permeability (Mur) = 1.0, height of upper shield (Hu) = 3.9e34 mil --- or some large value, since we don't have an upper shield---, metal conductivity (Cond) = 4.1e7, and metal roughness (Rough) = 0 mil.] After entering these values, you can save the file again.

5. Wall1 and Wall2 (in the Component Parameters area) allow us to specify the distance to metal sidewalls, if they are present. We are not using lines that have this type of shielding, so these values should be entered as zero, indicating to Linecalc that they are not to be considered in the analysis.

6. We are now ready to calculate the microstrip characteristics. First, let's use the **"analyze"** approach.

7. Change **W** (line width) to 3.0 mm and **L** (line length) to 100 mm and click on the Analyze button.

8. In the Electrical Parameters window, you should see that the resulting value of the characteristic impedance (**ZO**) is 50.0076 Ω and the electrical length (**E_Eff**) is 325.216 degrees. This length corresponds to the physical length of 100.0 mm, at the specified frequency (1.5 Ghz for this example) and using the calculated effective dielectric constant of the line. In the Calculated Results window: **K_Eff** (the <u>effective</u> dielectric constant) is 3.259, **A_DB** (the <u>total</u> attenuation on the 100.0 mm line) is 0.53 dB (which means this line has an attenuation of 0.0053 dB/mm), and the **Skin depth** is 0.079 mil (or 2 microns).

9. If you now change **W** to 2.0 mm and click on the analyze button, you will see that the parameters are recalculated (the characteristic impedance increases to 62.6 Ω, etc.)

10. Now we will try the **"synthesis"** approach.

11. Let's say we want to know the width of the line necessary to achieve a 40 Ω characteristic impedance. In the Electrical Parameters window, change **ZO** to 40. You can also specify a desired electrical length E_EFF. Now click on the Synthesize button.

12. You should find that **W** has increased to 4.286 (mm). The other parameters (such as the physical length **L** necessary to achieve the specified electrical length, **E_Eff**, as well as the parameters in the Calculated Results window) will also be automatically adjusted.

You should be aware that, in general, the routines used for the "analysis" calculations and the "synthesis" calculations may be different. This means that you may get slightly different results, depending on which direction you proceed with the calculations. This is more critical in geometries that involve more than one strip, such as the coupled microstrip lines described in the following procedure.

2. Using Linecalc to Characterize Coupled Microstrip Lines

One of the laboratory experiments involves a microstrip structure known as a coupled-line coupler. The procedure given below explains how to use Linecalc to analyze such a structure.

1. As described above, start Linecalc and save your file using File > Save as... and place the file in your project directory (or in the Networks subdirectory within your project directory). In this example, we will call the file micro-2.lcs

2. For this example, set the frequency to 1.5 GHz.

3. In the Component Type window, click on Select and specify the **MCLIN** (microstrip coupled line) element type. Click Apply and then OK to close the pop-up window. You may want to save your file again.

4. In the Substrate Parameters window, set the parameters for the substrate as described in the procedure above. For this example, we will again use **Er**=4.3, **H**=1.57 mm, **T**=0.043 mm, and **TanD**=0.022.

5. Now we are ready to do some calculations. Let's start in the "analysis" mode.

6. In the Physical parameters window, set **W** to 2.0 mm (the width of the two transmission lines), **S** to 1.0 mm (the spacing between the two transmission lines), and **L** to 100.0 mm (the length of the transmission lines). Now click on the Analyze button.

7. In the Electrical parameters window, you should see the following: **ZE**=73.7895 Ω, **ZO**= 48.8846 Ω, **Z0**= 60.0597 Ω, **C_DB**=-13.8493and **E_Eff**= 316.408. The first two parameters are known as the even- and odd-mode impedances (the second parameter is Z Oh, not Z zero); the meaning of these parameters will be explained in class, but for now suffice it to say that transmission lines with two strips plus a ground plane are typically considered to propagate two modes (an even mode and an odd mode). The third parameter is the characteristic impedance of the coupled microstrip line and is calculated as $(ZE * ZO)^{1/2}$. The fourth parameter is the coupling coefficient of this line **if** it were being used as a quarter-wavelength long, coupled-line coupler.

This is not always the manner in which these lines are used, but it is very common and so Linecalc computes this value automatically. (Remember that this coupling value is only correct at the frequency for which the lines are 90 deg. long, and only when each of the lines is terminated in a specific manner.) The last parameter, E_Eff, is the mean electrical length of the 100.0 mm long lines at the frequency specified (i.e., 1.5 GHz in this example). This is the mean value between the electrical lengths for the even and odd modes, which are slightly different because the propagation constant for the two modes is generally not the same.

8. Finally, let's examine the parameters in the Calculated Results window. **KE** and **KO** are the effective dielectric constants for the even- and odd-mode, respectively; the difference in these values leads directly to difference in the electrical lengths, as explained in the previous step. **AE_DB** and **AO_DB** are the total attenuation on the 100.0 mm long line for each of the modes. The last parameter is the calculated skin depth, thatis also dependent on frequency.

9. If we change **S** to 0.5 mm in the Physical parameters window and click the Analyze button, the Electrical parameters and Calculated Results will change accordingly. In this case, **ZE**= 77.7326 Ω, **ZO**= 42.3321 Ω, etc.

10. Now let's investigate the "synthesis" mode for this element. Here we have to be very careful not to send the simulator into deep space! If we want Linecalc to calculate the physical parameters (**W** and **S**) necessary to achieve certain even and odd mode impedances, we need to be sure that we initially set W and S to "reasonable" values. They do not have to be extremely close to the final values, but should at least be in the ball-park. One way to ensure this is true is to first run the simulator in "analyze" mode and specify values for W and S that are of the same order of magnitude as the substrate thickness. In this class, setting W to approximately 2 and S to approximately 0.5-1.0 will work in most cases.

11. Adhering to our guidelines, set **W**=2.0 mm and **S**=0.75 mm in the Physical parameters window.

12. Now let's assume that we are trying to design a -14 dB, quarter-wavelength coupled line coupler that has a characteristic impedance of 50 Ω. In the Electrical parameters window, set **Z0**=50 (Z zero, not Z Oh), **C_DB**=-14.0 and **E_Eff**=90 degrees. Now click on the Synthesize button.

13. In the Electrical parameters window, you will see that **ZE** and **ZO** were automatically changed to 61.207033 and 40.844979 Ω, respectively. In the Physical parameters window, **W**= 2.778250 mm, **S**= 0.865481 mm and **L**= 28.082700 mm. These results thus tell us the width, spacing and length of the coupled line coupler in order to achieve -14 dB coupling with a 50 Ω characteristic impedance (at the design frequency of 1.5 Ghz). NOTE: If you happen to get odd results, such as a line spacing (S) that is extremely small, return to step 11 and modify the results by approximately 10% and repeat step 12.