Differential_Measurements

Where To Find This Example

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Design Notes

Single Ended, Common, and Differential S-Parameters of Coupled Lines Using the MMCONV Element

This project shows how to measure differential and common mode S-parameters using the MMCONV model, which drives and views a coupled transmission line model in either common or differential_mode. This project will demonstrate a technique for determining the common and differential characteristic impedances of coupled lines. Single ended measurements are also shown.

Overview

Note: The substrate definition and model parameters for all of the schematics are located in the **Global Definitions** section of the project.

The 2-edge coupled lines model S2CLIN can correspond to two PCB traces or transmission lines used in pairs for differential signals.

Common mode is when the two lines at one side of the structure are driven with equal amplitude and equal polarity, such that the currents will be traveling in the same direction on the lines.

Differential mode is when the two connections at one side of the structure are driven with equal amplitude and opposite polarity, such that the currents will be traveling in opposite directions on the lines.

Single ended mode of a coupled line is when one port is excited and all others are terminated.

A coupled line will have characteristic impedances for both common (ZC) and differential (ZD) mode. These impedances are related to odd (ZO) and even model (ZE) impedances of a line. ZO and ZE are what are calculated in TXLine for coupled lines. They are related by the following equations:

ZD = 2*ZO

ZC = 0.5*ZE

Common Mode Schematic

In the "Common_Mode" schematic, one port drives both of the coupled lines on each end. Both lines of coupled lines are driven with identical signals. This can be simulated by a port hooked to one of both lines.

Differential Mode Schematic

In the "Differential_Mode" schematic, the lumped element transformer creates the differential drive on each end of the coupled transmission line.

Differential and Common Mode MMCONV Schematic

The MMCONV model allows both the common mode and differential mode of the coupled lines to be viewed simultaneously.

Single Ended Schematic

S-parameters are measured with unused ports terminated. By simply connecting a port to each of the 4 ports of the coupled line model S2CLIN, we create single ended measurements because one port is turned on and the others are terminated when measurements are made.

Single Ended, Common, and Differential Results

For a differential line, if the spacing between the lines is such that coupling is minimized, the common, differential and single ended impedance of the lines should be identical. Change the equation in the **Global Defintions** "Gap=2**"** to **"**Gap=75**".**

Look at the graph "SCD S11" to see the S11 parameter from all of these simulations are different. This is with all of the port impedances set to 50 ohms. Try setting the "zport" variable in the "Common_Mode" schematic to 25 and the "zport" variable in the "Differential_Mode" schematic to 100 and look at the same graph. Notice that the measurements are identical. Please reset the "zport' values to 50 for both schematics. Also please set "Gap=75**"** back to **"**Gap =2**".**

MMCONV Element

The MMCONV schematic model is used to look at the common and differential response of coupled lines in one schematic. Please see the "Differential_And_Common_Mode_MMCONV" schematic to see how this is configured. To look at the differential s-parameters, you would use the regular s-parameter measurements and use the ports connected to the "Diff" node of the MMCONV model. So in this schematic, ports 1 and 3 are used for differential s-parameters. To look at the common s-parameters, you would use the ports connected to the "Comm" node of the MMCONV model. So in this schematic, ports 2 and 4 are used for common s-parameters.

To verify that the MMCONV model is equivalent to the common and differential configurations already shown, see the graphs, "Differential S11" and "Common S11". You will see that they are identical. If they are not identical, then you probably don't have the same port impedances set. Notice that for the "Common S11" graph, the port index is actually 2 for the measurement for the "Differential_And_Common_Mode_MMCONV" schematic. This is the input port for the common mode excitation.

How to Determine Single Ended, Common, and Differential Characteristic Impedance

It is simple to determine the differential characteristic impedances of the different line modes in AWR. To do this:

1) Set all port impedances to a variable.

2) Tune or optimize on the port impedance variable until S11 of the coupled line is either at the center of the smith chart or at a minimum value when plotted in dB on a rectangular graph.

3) The characteristic impedance is the impedance set for the ports when S11 is minimized.

To demonstrate, open up the "Single_Ended" schematic and the "Single ended Impedance" graph. Tune on the "zmixed" variable until the response is at the center of the smith chart. This value will be approximately 32.5 ohms.

Now, the differential and the common_model characteristic impedances can be found the same way in the "Differential And Common_Model MMCONV" schematic. For the common impedance, tune on "zcommon" and look at the "Common Mode Impedance" graph. You will find this value to be approximately 22 ohms. Now tune on "zdiff" and look at the graph "Differential Mode Impedance". You will find this value to be approximately 47.8, which is ZD for this structure.

To make sure these values make sense, use Txline (from the **Tools > TXLine** menu item) to calculate the even and odd mode impedances for a coupled stripline model with the same substrate parameters. You will find ZO = 23.7 ohms and ZE = 44.2 ohms. The equations provided earlier will be very close for these values and the values determined for ZD and ZC.

ZD=47.8 ohms 2*ZO = 47.4 ohms

ZC=22 ohms 0.5*ZE = 22.1 ohms.

Finally you could calculate different to common mode conversion by looking at s-parameters with a differential port as the excitation and a common port as the termination port. The same is true to calculate common to differential mode conversion. This exercise will be left to the user.

MMCONV Visualization

To help visualize what the MMCONV element does, this project contains three schematics to demonstrate. All three schematics have their frequencies set locally to the schematic to 5 GHz. The tone 1 harmonics for the project is set to 128 to create a good square wave.

First, look at the "Square_Input_MMCONV" schematic and see that this is just containing the MMCONV model and some ports. The differential node is driven with a PORT_SQR with amplitude of 5 volts. To verify the input signal, please see the "Square Input Signal" graph. The common node is grounded. Therefore, the signal at the other side of the MMCONV should be the input signal split into a differential signal. Please see the "Square MMCONV Output" graph to verify this. The square waves are opposite in polarity and half of their original magnitude, thus a differential signal.

The schematic "Square_Input_MMCONV_With_Line" is identical except a coupled line was added. Now look at the graph "Square MMCONV After Line" to see the effects the line had on the square waves running through. Notice that the corners are rounded (due different attenuation at the different harmonics of the square wave) and the phase shift introduced by the lines (look at the rise and fall locations compared to the "square MMCONV output" graph).

Finally, there is the schematic "Square_2_MMCONV_And_Line". Now the signals are being combined together using the MMCONV, and ports are connected to the "Diff" and "Comm" nodes of the model. The graph "Square MMCONV Output Comm And Diff" shows the response at the output. The signals on the lines are purely differential so the entire signal shows up on the "Diff" port and none on the "Comm" port. There is an additional line after the coupled line to show the effects of differential to common_mode conversion, its original value is zero so there is no such conversion. Now turn on the tuner and see that at a particular length (approximate 555 mils or half wavelength at 5 GHz), the entire differential signal is converted to common_mode.

EM Structures as Coupled Line Model

For this example, the S2CLIN coupled line model used in the simulation is an EM Quasi-static parameterized circuit model. The model used could be any coupled line model. The model could also come from an EM structure in this project. The project setup would be identical except the subcircuit of the EM simulation would be used in replace of the S2CLIN. This would allow you to analyze the different modes from the results of an EM structure.

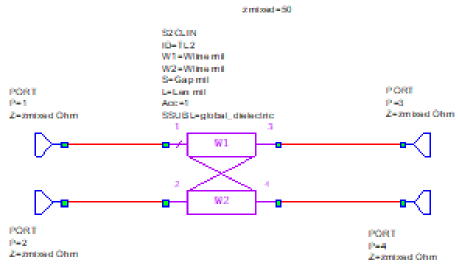
Bit Pattern Simulations

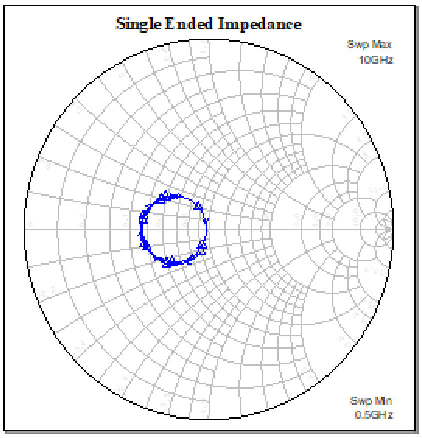
If you wanted to look run bit patterns through a differential coupled line, you would have the same setup as is shown in the "Differential_And_Common_Mode_MMCONV", except that port 1 would be replaced with a PORT_ARBS (for a user-defined bit pattern) or a PORT_PRBS (for a pseudo-random bit pattern). You could then setup measurements to look at voltage eye diagrams at port 3, the differential output port. See the Eye Diagram examples folder for more details on Eye measurements.

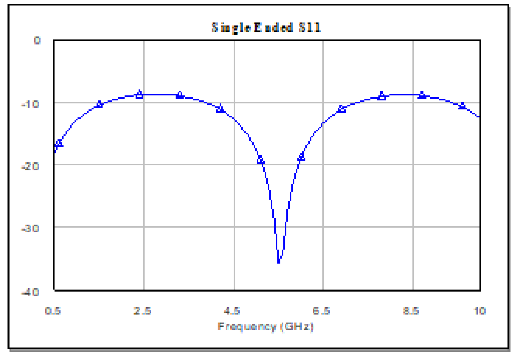
Global Substrate Definitions

All transmission line structures, such as microstrip, stripline, or CPW (coplanar waveguide) require a substrate element such as MSUB, SSUB, or CPW_SUB to specify the substrate parameters. Whereas these substrate definition elements often appear in the schematic of the transmission line, in this project one SSUBL substrate element for a two layer stripline appears in the "Global Definitions".

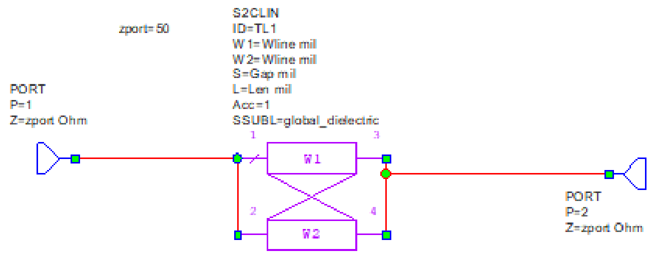
Schematic - Single_Ended

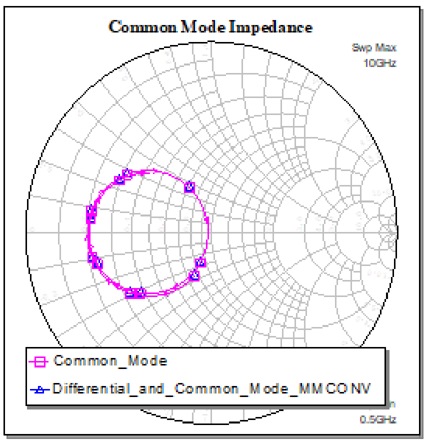


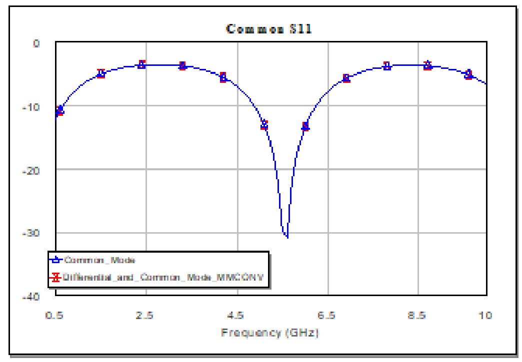




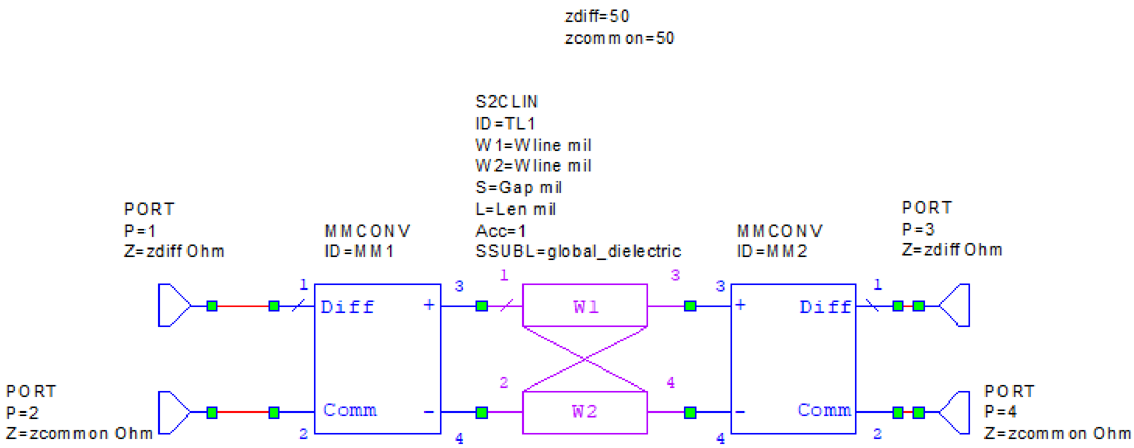
Schematic - Common_Mode

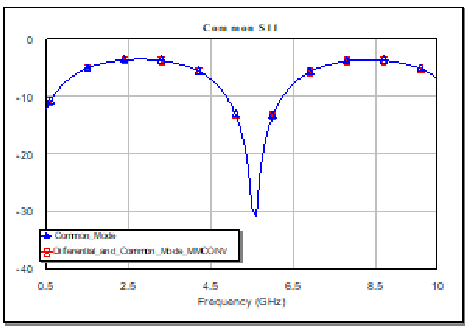


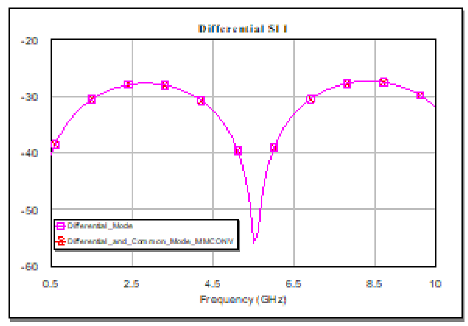




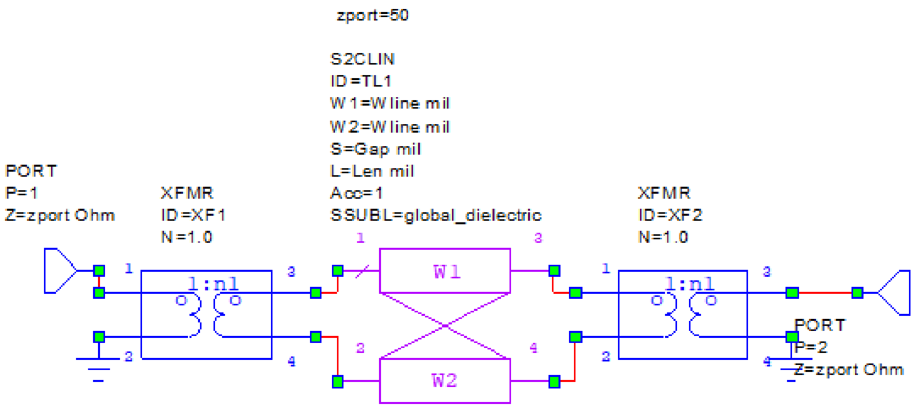
Schematic - Differential_and_Common_Mode_MMCONV







Schematic - Differential_Mode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S=Gap mil
L=Len mil
Acc=1
SSUBL=global_dielectric
PORT
P=1
Z=zport Ohm
XFMR
ID=XF1
N=1.0
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W1
W2
PORT
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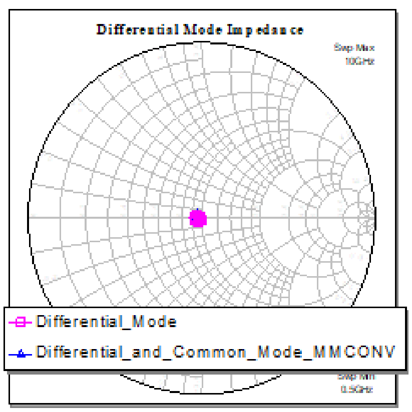
Z=zport Ohm


Differential Mode Impedance
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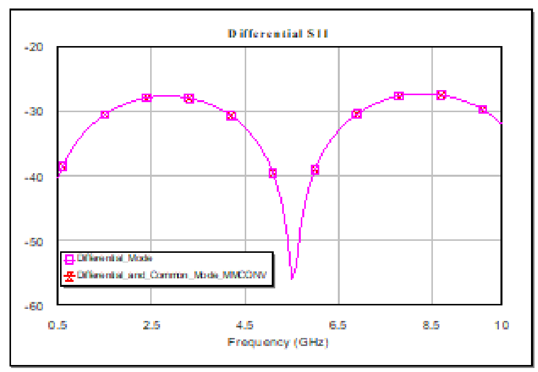
Swp Min
0.5GHz
Differential_Mode
Differential_and_Common_Mode_MMCONV


Differential S11
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-40
-50
-60
0.5
2.5
4.5
6.5
8.5
10
Frequency (GHz)