**Sonnet Suite Application Note**

# *Analysis of planar differential lines with Sonnet*

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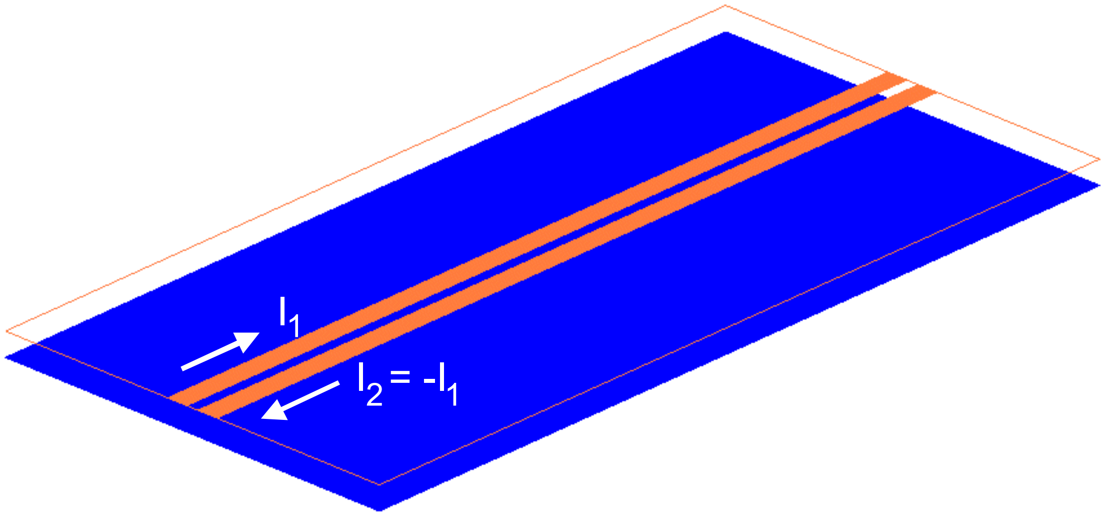
## Key Words

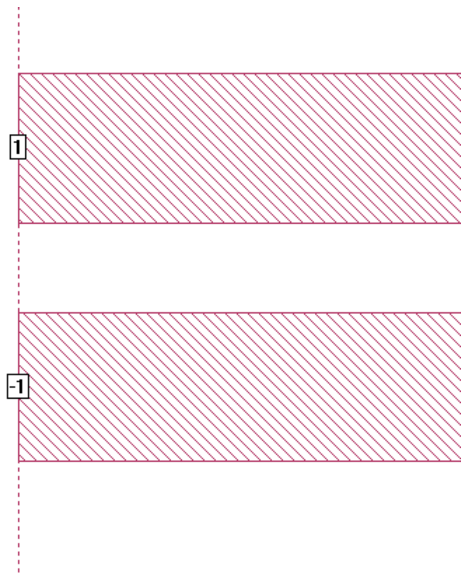
differential line impedance $Z_{diff}$
differential ports
push-pull port
characteristic line impedance $Z_{line}$
odd mode impedance $Z_{odd}$

**Introduction:** This application note describes the configuration and analysis of differential lines in Sonnet. A differential line consists of a differential pair of traces and has in most cases also a ground reference plane. As example, the picture below shows a pair of transmission lines over a ground plane.




In the differential mode, the second signal trace carries the back current of the current through the first trace ($I_2 = -I_1$). There would be no current at all through ground.

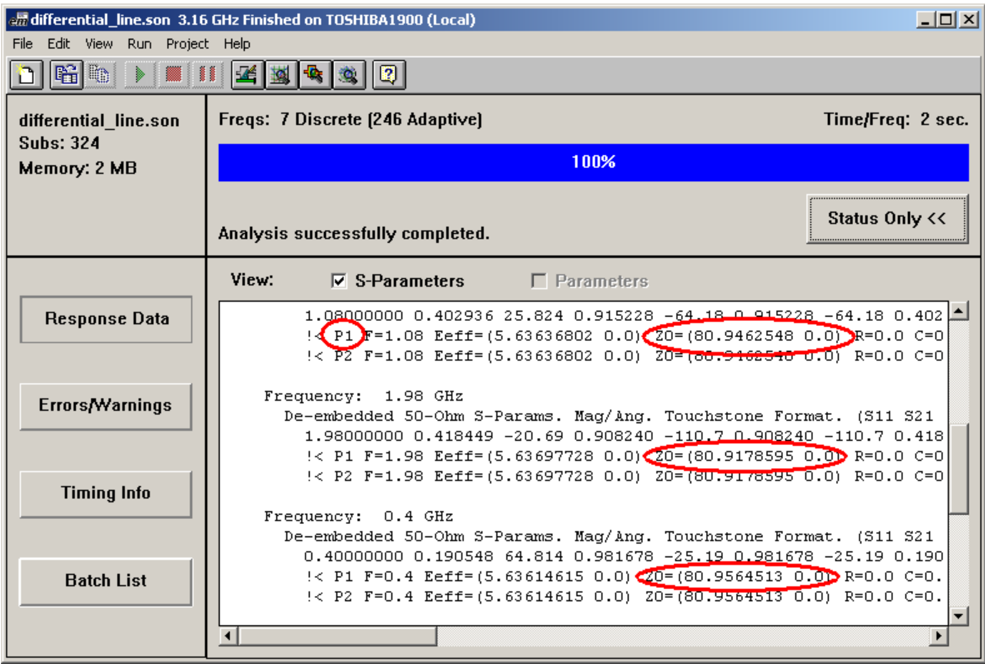
With Sonnet, you can easily determine the differential impedance $Z_{diff}$ of the traces. For that, add a port to the first trace, and then add a second port to the other trace. After adding the ports, you have to change the port number of the second port to the same number as the first, but with a minus sign. If the first port has the number "1", the second port must have the number "-1". Below is a screen shot of such a pair of differential ports in Sonnet (in this example, box wall ports have been used). Please note that this port configuration is also called *push pull ports*.



After your Sonnet project has been analyzed, you can identify the differential impedance $Z_{diff}$ of the lines in two ways.

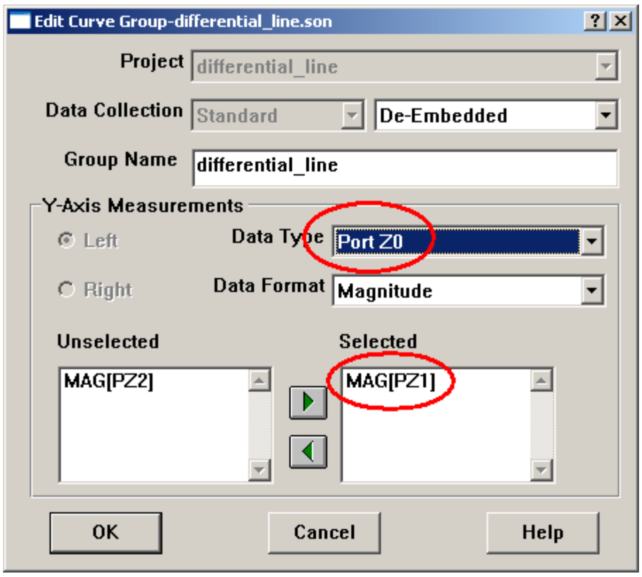
For each frequency analyzed, a characteristic line impedance $Z_{line}$ will be calculated and displayed in the analysis batch output window. If the two signal traces are connected together with a load that has the line impedance value as shown below, the reflection is zero.


In the analysis batch output window you will find for each port number and frequency a line with a statement similar to “!< P1 F=1.08 ….. Z0=(80.9462648 0.0) …” as shown in the screen shot below.

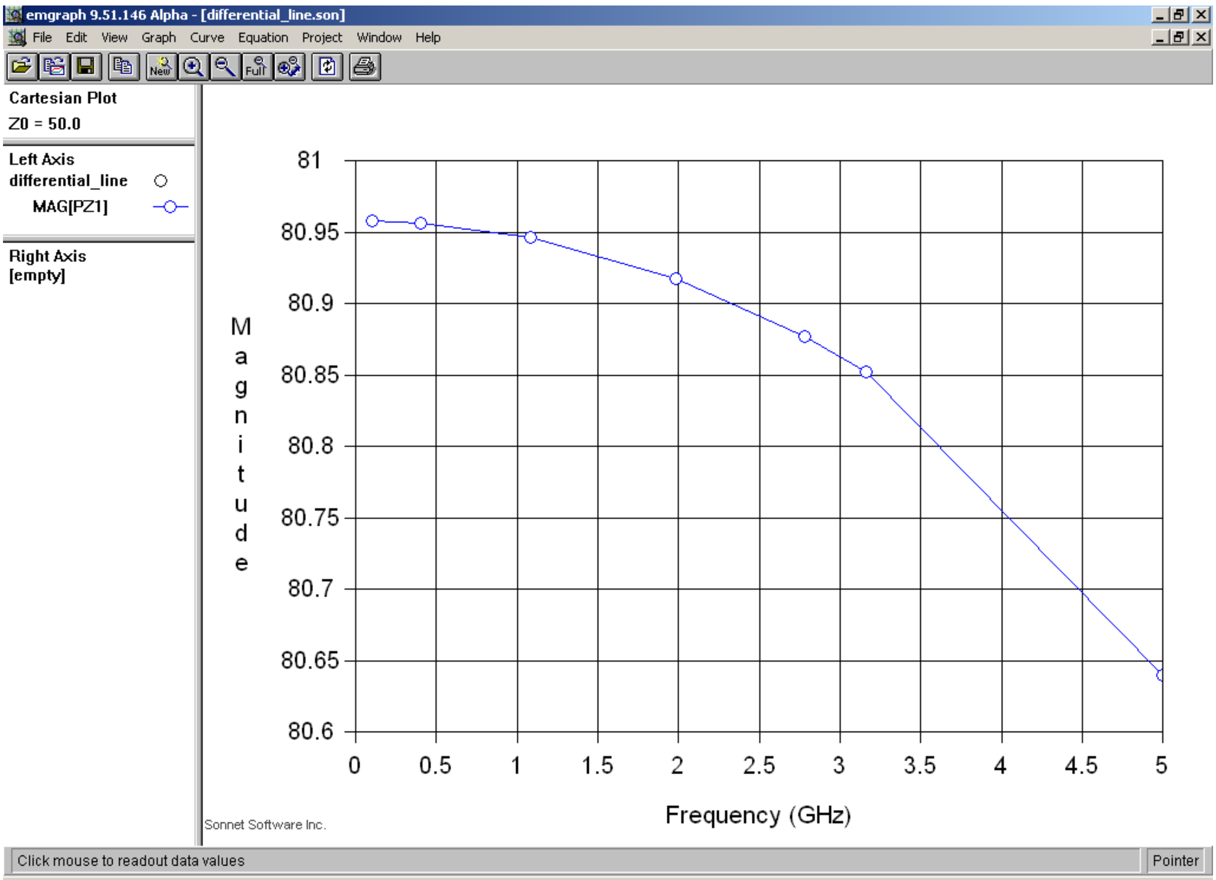



This means that in this example the line pair that is connected to the ports “+1/-1” has a line impedance $Z_{line}$ of about 81Ohm. As this line is a differential line, the displayed impedance is the identical with differential impedance $Z_{diff}$. *Please be not confused about the name “Z0”, this is just a general notation.*

A more convenient way is to plot the line impedance in the Sonnet response viewer. In the response viewer, change the *Data Type* to Port Z0, and the *Data Format* to Magnitude. Then, select MAG[PZ1] from the list on the left hand side as shown in the next screen shot. This will plot the frequency dependent differential line impedance for port 1.




As shown in the screen shot below, the line impedance is plotted for each analyzed frequency. Please note that a line impedance value is only evaluated at the em simulated frequencies and not for ABS interpolated data.



**Relation between differential impedance and odd mode impedance:** RF and microwave engineers consider a pair of signal traces as two coupled transmission lines. The differential operating condition of the pair is one of two possible "modes", which is called *odd mode*. The other possible mode would be the *even mode*. These two modes are usually characterized with the odd mode impedance $Z_{odd}$, and the even mode impedance $Z_{even}$. The values of these impedances depend on the material (permittivity) and geometric parameters (line width, distance, and height) of the line pair.

The odd mode impedance $Z_{odd}$ and the differential impedance $Z_{diff}$ have a different definition, but are very closely related:

$$Z_{odd} = Z_{diff} / 2 \quad \text{or}$$

$$Z_{diff} = 2 \cdot Z_{odd}.$$

References:

[1] "No Myths Allowed: Differential and Common Impedance", Dr. Eric Bogatin, *Printed Circuit Design*, October 2002, http://www.pcdandm.com/archives/pcdmag/pdf/0210/0210col3.pdf

[2] "Differential Impedance: What's the Difference?", Douglas Brooks, *Printed Circuit Design*, August 1998, http://www.ultracad.com/diff_z.pdf