Engineering ElectroMagnetism

Experiment - 5

Study of differential mode in a transmission line using HFSS

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Aim:
To simulate and analyze the model of a stripline differential pair using HFSS software

Components or Software required:
Ansoft HFSS software

Theory
Differential signalling is a method for electrically transmitting information using two complementary signals. The technique sends the same electrical signal as a differential pair of signals, each in its own conductor.
It is almost impossible to increase data rates and lower power consumption at the same time without making use of low voltage swings. But using lower voltages for operation may severely affect signal integrity and the data received might be often corrupt due to noise components added in the interconnects.
Low Voltage Differential Signalling (LVDS) is a method used to communicate data at a very high-frequency rate using a low voltage swing. This is primarily done by utilising two traces/lines instead of one over the substrate to transmit differential signals over them. This differential method of transmission is less susceptible to common-mode noise as it considers the difference between the 2 signals at the receiver thus ignoring the noise that appears on both lines. Because of this effect, we can use low voltage in our circuits which otherwise would not have been possible due to the presence of noise. This low voltage swing helps in increasing the data rate and helps lower power consumption which otherwise wouldn't have been possible.
LVDS's proven speed, low power, noise control, and cost advantages are 2 popular in point-to-point applications for telecommunications, data communications, and displays. LVDS uses high-speed analogue circuit techniques to provide multi-gigabit data transfers on copper interconnects.
In a stripline, the total voltage at a particular position on one of the lines is dependent also on mutual impedance (through current flowing in the other line as it also induces some voltage on the line chosen because of less distance between them) along with being dependent on the characteristic impedance of the line (through current flowing in that line).
When we have a pair of lines close to each other, it is fair to say that the presence of a current in line 2 will induce some voltage in line 1 and a current in line 1 will induce some voltage in line 2. Thus, the voltage 'V1' at line 1 will not only depend on current 'I1' in line 1 (through impedance 'Z0' of line 1). It will also depend on the current 'I2' in line 2 through coupling or mutual impedance 'Zm' between lines 1 and 2. Closer are the

two lines to each other, greater is the coupling between them. In fact, if the separation ‘S’ between the lines is reduced, the values of all three parameters – ‘Lm’, ‘Cm’ and ‘Zm’ – increase.

OUR MODEL

An edge coupled differential symmetric stripline transmission line is constructed with two traces referenced to the same reference planes above and below the traces. There is a dielectric material between them. There is also some coupling between the lines. This coupling is one of the features of differential traces.

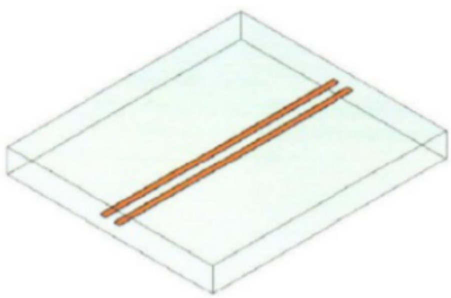
We created the following stripline differential-pair model on ANSYS HFSS :

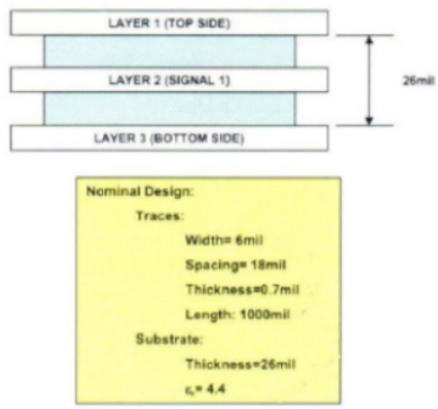
Substrate Material: FR4 (εr = 4.4)

Trace Material: pec (perfect electric conductor)

Substrate Dimensions : 220mil x 100mil x 26mil

Trace Dimensions: Width: 6 mil Thickness: 0.7 mil Length: 100 mil Spacing: 18 mil



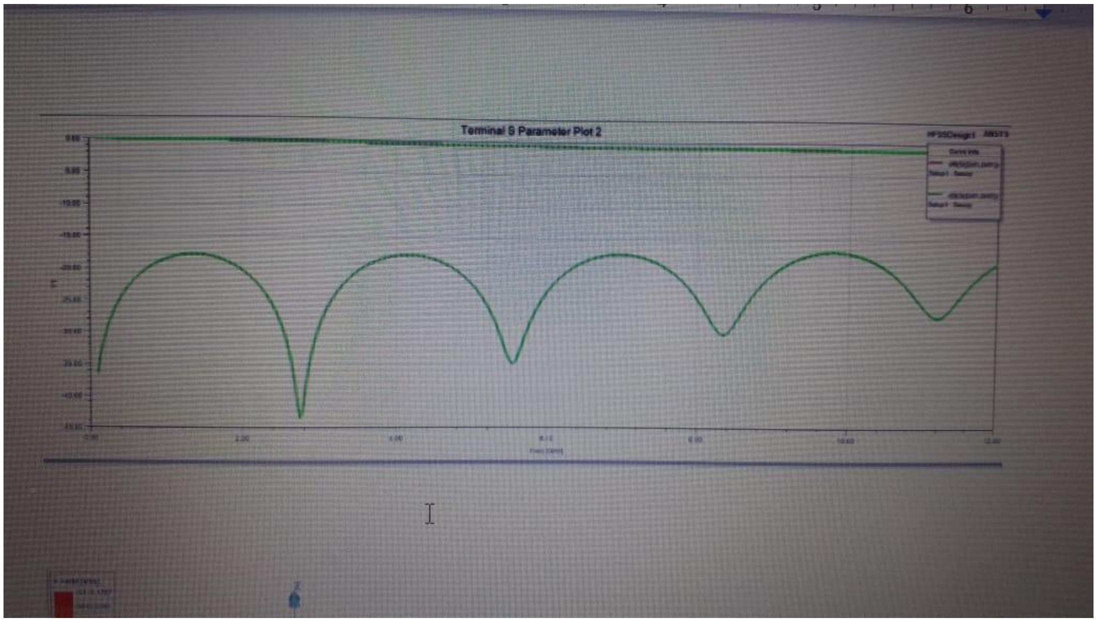


Procedure:

1. Change the units to mil and terminal to waveport. Use HFSS to create the stripline differential pair geometry.
2. Select the material FR-4 and PEC for the 2 respectively, and define the dimensions.
3. Choose Excitation and assign differential pair
4. Set De-embedding and Boundary Display
5. Create Analysis Setup and add Frequency Sweep
6. Save project, validate the model and analyse
7. Check Solution Data to create Differential pair S-Parameter Plot. Plot Field Overlay.
8. Set sources in common mode, repeat the above procedure and Plot Field Overlay. Compare the fields in these different modes of excitations.
9. Determine the characteristic impedance Zd of the transmission line in the differential mode and compare it with the theoretically obtained value.

Observations and Results

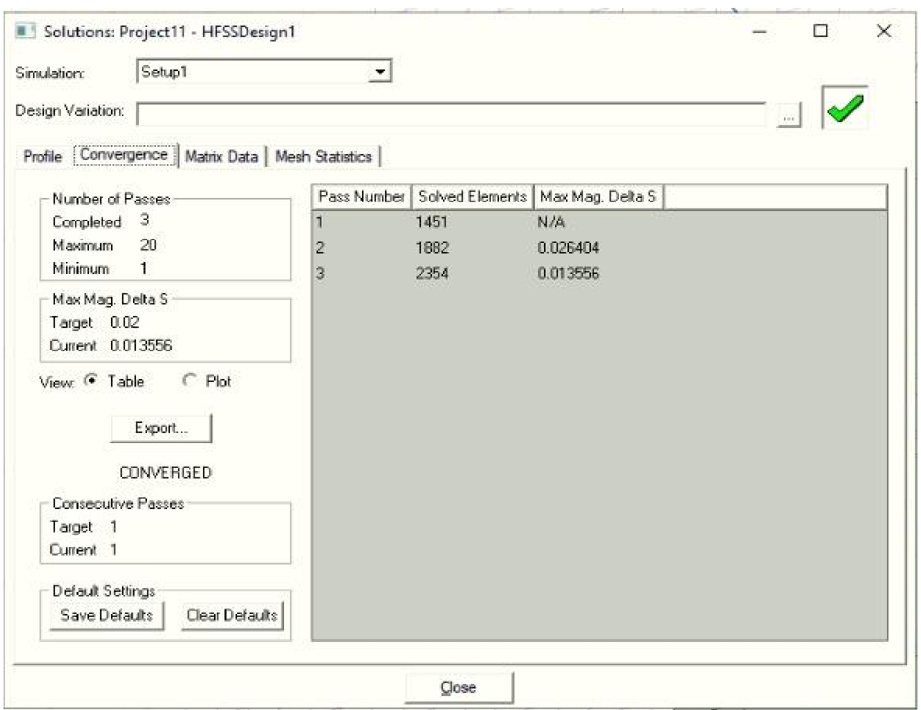
1. S parameter plot



We have the following observations from the graph

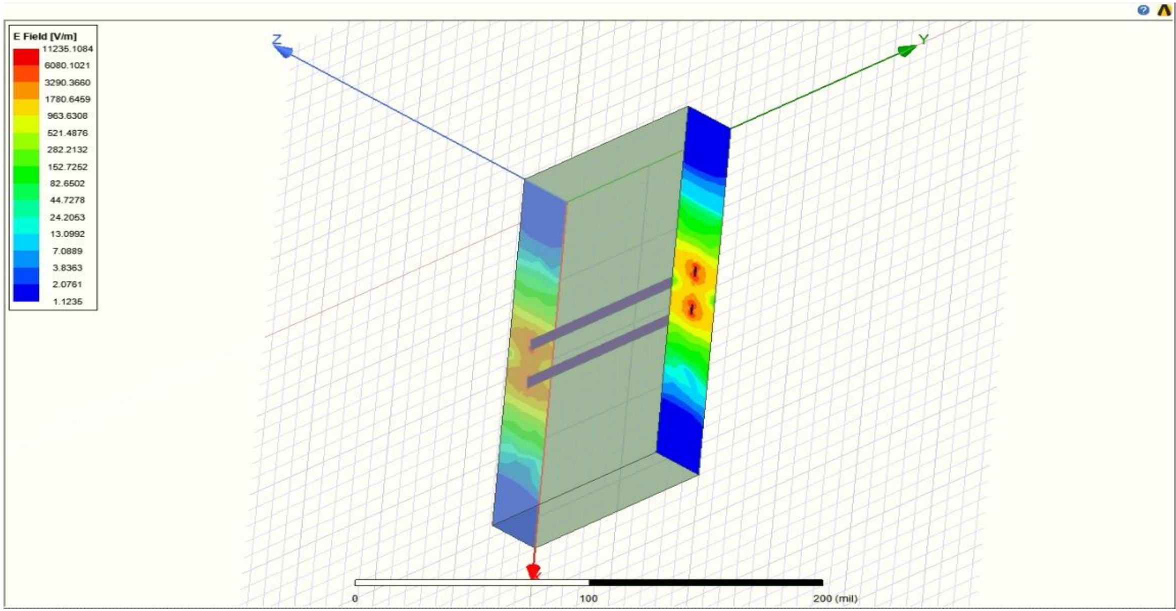
- S(Diff1, Diff 2) stays less than 0 dB shows that there is negligible gain/Loss
- S(Diff 1, Diff 1) stays below -15dB which shows that it is a decent design.

2. Delta S with no of passes

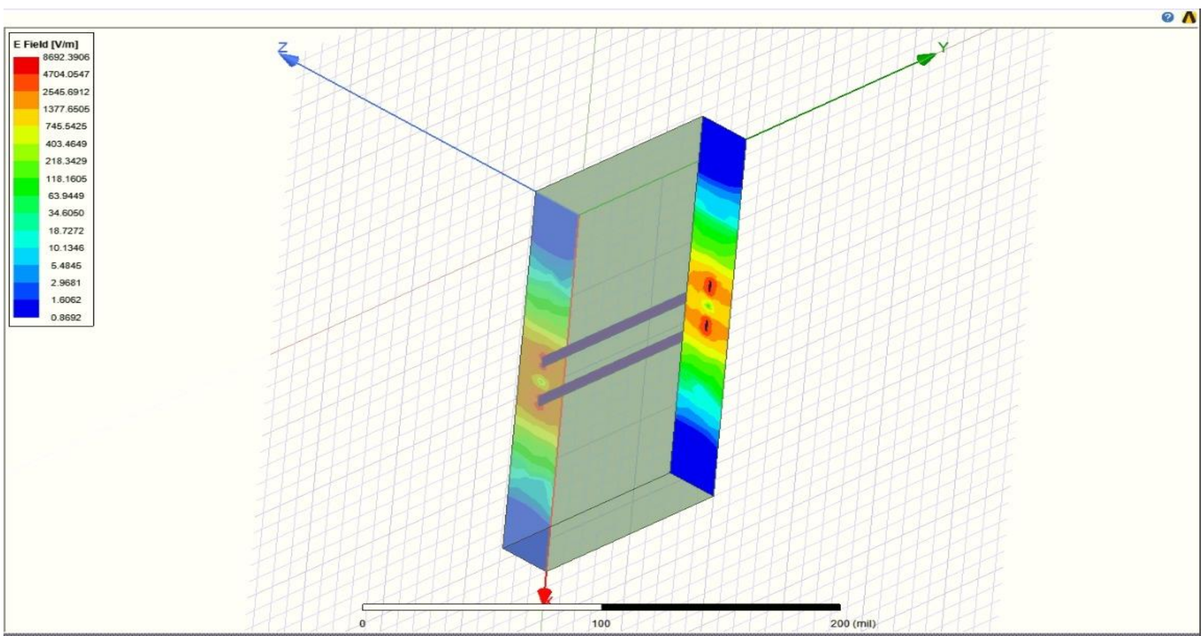


We can see that just after 3 passes our error is under the limit of 0.02%.

3. Variation of the electric field



Variation of E field for 180 degrees.



Variation of E field at 0 degrees.

We can understand the above pattern with skin effect.

Skin effect:- the tendency of electric AC current to distribute within a conductor such that current density is more near the surface and decreases with depth.

The theoretical value of differential impedance can be calculated from the following :

$$Z_d = \frac{120}{\sqrt{\varepsilon_r}} \ln\left(\frac{1.9(2h+t)}{(0.8w+t)}\right)\left(1-0.347\exp\left(-2.9\frac{d}{2h+t}\right)\right)$$

Note: valid for (w/h) from 0.1 to 2.0, and (t/h) less than 0.25

where

w = Trace width
d = Trace separation
t = Trace thickness
h = Dielectric thickness
ϵ_r = Relative dielectric constant

Using the above formula we got the value of differential impedance to be

Zd (theoretical) = 120.7 Ω

Also from the experimental results, we got the empirical value of differential impedance to be

Zd (empirical) = 121.7 Ω

Discussion and conclusion

Now to calculate the relative error between the theoretical value of differential impedance and the empirical value of the differential impedance we got

Error = $|Zd(theoretical) - Zd(empirical)|\ Zd(theoretical)$ * 100 %
= 0.83%

So, the error comes out to be 0.83%

Thus, We have simulated the model of stripline differential pair (LVDS) and observed the field distribution, S and Z parameters which have all been under our expectations according to our theoretical understanding.