

STRIPLINE OR MICROSTRIP: Which is better for EMC?

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Abstract:

This article talks about the two most commonly used routing configurations on PCBs – Microstrip and Stripline configurations. The article covers the basic structural differences, impedance calculation formulas and analysis of emission performance in a 3D simulation environment for both the configurations.

Background:

I felt providing a bit of background on the microstrip and the stripline configurations would definitely help a few readers. If you are already familiar with these configurations, then feel free to move on to the next section.

In simple terms, the Microstrip is a layout configuration where a signal trace is routed on top of a ground reference. The trace is generally present on the top or the bottom layers on a multi-layered board. An example of a microstrip configuration is shown below.

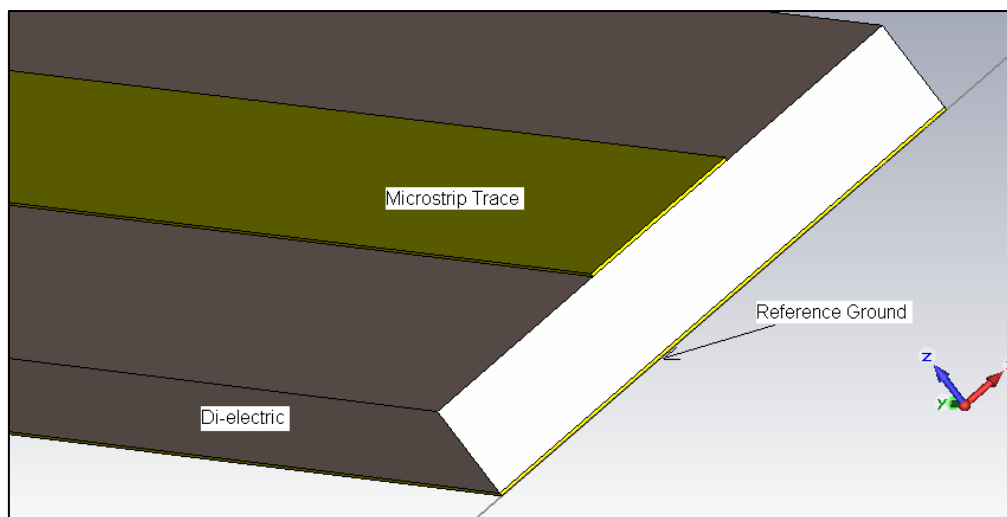


Figure: Microstrip Configuration

So in this configuration we have typically a FR4 dielectric surrounding the trace on one side while air surrounding it on the other.

On the other hand, in a stripline configuration, the trace is sandwiched between two ground layers providing the trace an excellent reference and shielding on both sides. The downside being that it generally requires more layers and it is not possible to achieve this configuration with a 2 layer board.

An example of stripline configuration can be seen below.

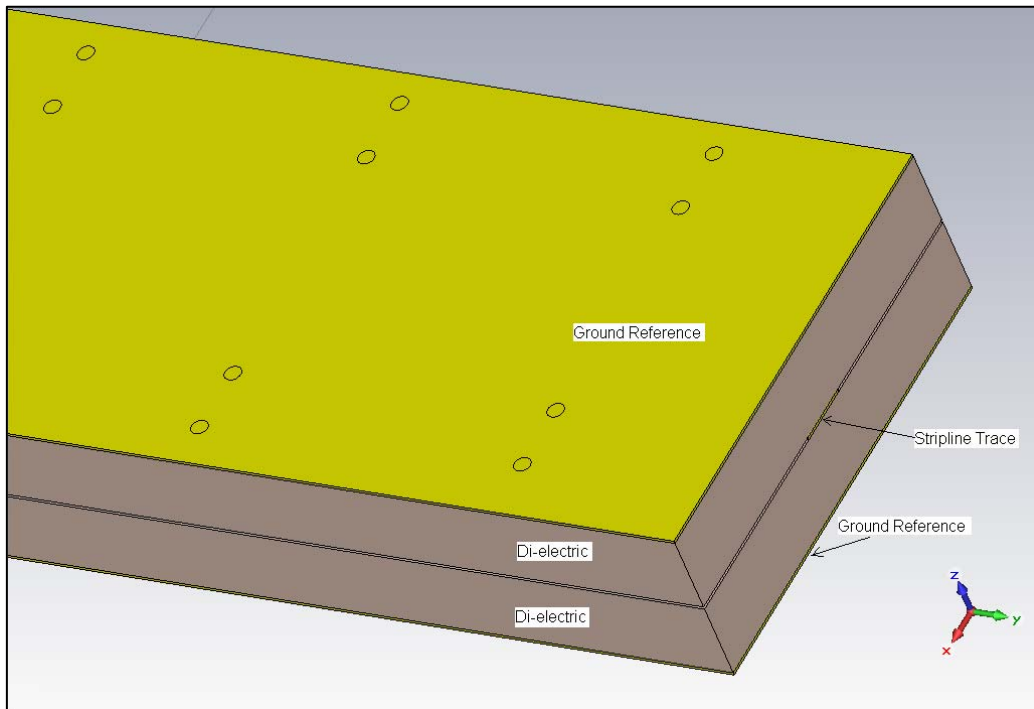


Figure: Stripline Configuration

There are a few more configurations that are commonly used which tend to be derivatives of either microstrip - called the embedded microstrip or the stripline - called the dual stripline. Please note that we will not be discussing about these configurations in this article.

Introduction:

As electronics engineers, we tend to use both Stripline and Microstrip configurations quite a lot and most of us (including me) prefer a Stripline and try and avoid microstrip wherever possible. Though many favour the stripline configuration, I think we generally are not aware of the performance difference between the two configurations. Striplines have the same relative dielectric constant on both sides of the trace and have better grounding/reference when compared to a microstrip configuration where the relative dielectric constant (ϵ_r) of typically around 4.5 (for FR4) is on one side while a ϵ_r of 1 (for air) is on the other side. The stripline trace is also slower than a microstrip because the effective ϵ_r of microstrip is lesser than the strip line's. So, what do these mean in terms of emissions? Does it mean that the one configuration is better for EMC than the other even if designed

properly? If so, what would be difference in emission levels between the configurations? One of the ways to answer these questions was to simulate these traces on a 3D simulation environment and plot the near fields associated with each trace to derive a direct comparison between the two systems. For this I used Microwave studio from CST - a fully integrated 3D simulation tool that can be used to compute S-parameters as well as E&H-fields.

Model Construction:

Before actually constructing my model, I used the following formulae to compute the trace impedance of both the microstrip and stripline traces. Alternatively, one could use calculators available in the internet to do the same job.

Microstrip⁽¹⁾:

$$Z_0 = \frac{87}{\sqrt{\epsilon_r + 1.41}} \text{Ln} \left(\frac{5.98H}{.8W + T} \right)$$

Where,

W – Trace width

H – Di-electric thickness

T – Trace Thickness

Er – Relative di-electric constant

Stripline⁽¹⁾:

$$Z_0 = \frac{60}{\sqrt{\epsilon_r}} \text{Ln} \left(\frac{1.9(2H + T)}{.8W + T} \right)$$

Where,

W – Trace width

H – Di-electric thickness

T – Trace Thickness

Er – Relative di-electric constant

I did this to make sure the source impedance (input port in the model) the transmission line and the termination impedance (output port in the model) are of the same value –in order to have maximum energy transfer.

I then selected arbitrary board dimensions of 50.8mm x 25.4mm and considered just two layers for my microstrip model - each with 35um of copper with a di-electric of 1mm thickness between them. The di-electric I considered was lossy FR4 with a relative di-electric constant of 4.9. If you substitute these values in the formula for Microstrip traces above, then you would see that to get an impedance of 50ohms, the trace width has to be 68 mils (thou).

Now, with the trace dimensions, copper thicknesses and the FR4 thickness in hand, all I had to do was to construct a board model in CST. It is fairly straight forward job and if you know CST, then you would probably know how easy it is to construct a board of this sort.

I did a similar job for the stripline configuration and using the equations shown, I calculated the trace width to be 28 mils in to achieve fifty ohm impedance. I then constructed a stripline

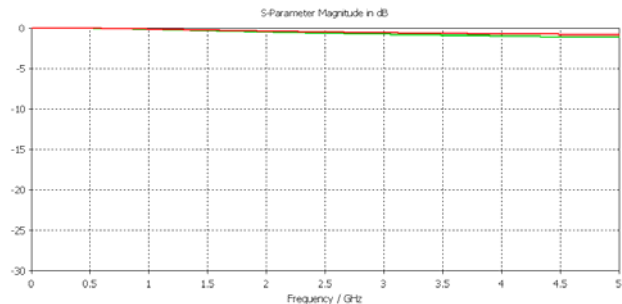
configuration model in a similar way as the microstrip model.

Simulation set-up:

Once I had the traces constructed, I then terminated the two ends of both the microstrip trace and the stripline trace with a 50 ohm port to match with the calculated trace impedance. I added a few field monitors to monitor the 3D field, which I later used to calculate near field that would contribute to crosstalk. I then used a transient solver to compute the S11 and S21 of the traces over 0-5GHz frequency range.

Simulation Results:

Now to the most interesting bit - the results. As mentioned before I simulated both S-parameters and 3D fields on both the configurations. The S2,1 for both the configurations are shown below.



At 2.5GHz, the Microstrip was 0.15dB better than a Stripline, which gradually increases to 0.27dB at 5GHz.

This clearly shows that both the traces have been designed for maximum transmission which makes it easier to compare the emission performance side-by-side. So there is very less difference between the stripline and microstrip configuration when the traces are designed with proper impedance matching. The 3GHz would be the realistic maximum frequency of interest for many high speed applications and both the configurations perform almost equally and achieve similar levels of transmission and loss when designed with the exact characteristic impedance in each case.

On the 3D results, I calculated the field at 1mm perpendicularly above the traces assuming an input power of 1mW into the trace. We could see that the H-field is stronger in the Microstrip configuration

when compared to the stripline configuration. So, when an input power of 1mW was assumed the value of the simulated peak H-field at 1GHz from a stripline trace was found to be 0.141 A/m. With this data the field in dBmW can be calculated (considering the impedance to be 50 ohms) to be -8.01dBm, while the same trace at 200MHz had an H-field content of -8.51dBm.

The microstrip trace at 1GHz had a near field content of was around +10.36dBm which was about 18dB more than the stripline trace while at 200MHz it had a H-field of +9.66dBm, which means that the stripline has definitely better emission performance when compared with the microstrip. In general terms, we could say that the microstrip trace is around 15-20dB worse than its stripline counterpart.

Conclusion:

The Stripline configuration is arguably the best configuration out of the two that we discussed in terms of emission performance winning the microstrip by over 15dB. One point to remember though: this is an ideal scenario with perfectly matched impedances from the driver to the receiver. In real life we do not have a single trace on the PCB but hundreds of them. Although matching impedance is one major area of focus for a good layout design there are many other considerations one should bear in mind - like crosstalk, ground loops, etc. In the next article, I shall discuss about right angle bends in PCBs and their effect on emission performance. So Watch out!

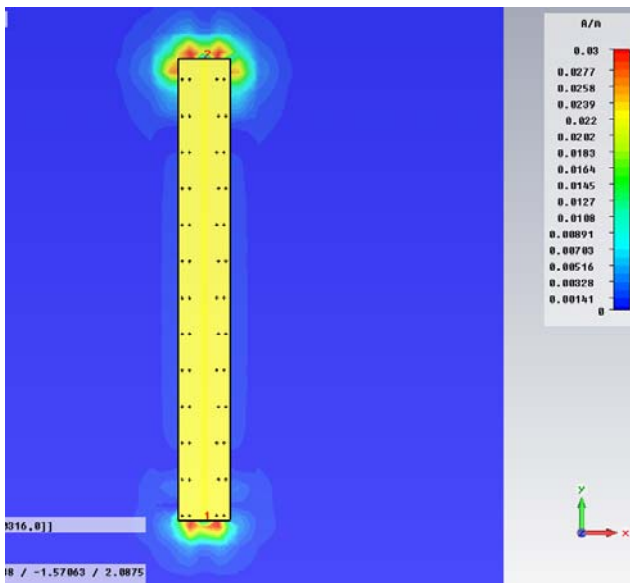


Figure: Stripline Emissions at 200MHz

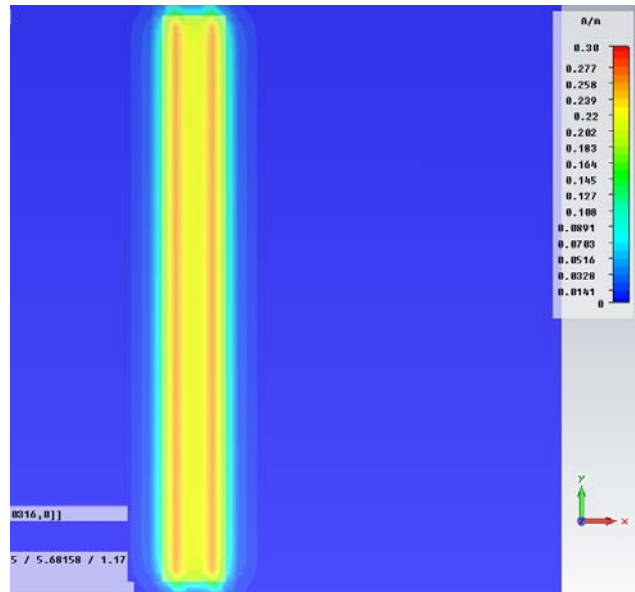


Figure: Microstrip Emissions at 200MHz

References:

- 1) <http://www.ultracad.com/articles/formula.pdf>