Via Stubs: How long is long?

Karthik Raj Guruchandran
www.basebandhub.com

Abstract:

Most PCBs made today are cost sensitive and use traditionally drilled vias. In a multilayer PCB, these vias are mechanically drilled after the layers are bonded together to form a complete PCB. After all the traces are etched and bonded, the PCB is finally drilled and plated to form vias between layers that connect traces. On PCBs that are 1.6mm thick and have less number of layers, the vias that travel across the top and bottom layers of the PCB do not have enough stub length to create problems at reasonably high frequencies. But on PCBs with higher layers which can have a total PCB thickness of about 5mm and above, any vias present, will have a definite impact on signal integrity.

Back Drilling:

To avoid signal integrity issues, many high speed but miniature designs go for a blind and buried via approach - an approach that is very good from an engineering point of view but costs a lot. The same approach of blind and buried vias however cannot be applied for backplanes and other similar designs which have high speed signals and also have enormous number of tracking layers and a very thick PCB. Here manufacturers use a technique called back drilling.

Back drilling is a process of drilling the vias that are plated with a slightly bigger drill, effectively removing the extra length of via that forms a stub. But this process is not cheap and has a cost impact associated with it. The cost is directly related to how far the PCB has to be back drilled and also how many different vias need to be back drilled. So instead of back drilling all the vias to the minimum possible stub length, it will be wise to decide on the vias associated with high speed traces and back drill them to suitable stub lengths. But how do we decide on a suitable stub length? That was the exact question I had in my mind and I thought I might get an answer simulating a similar structure.

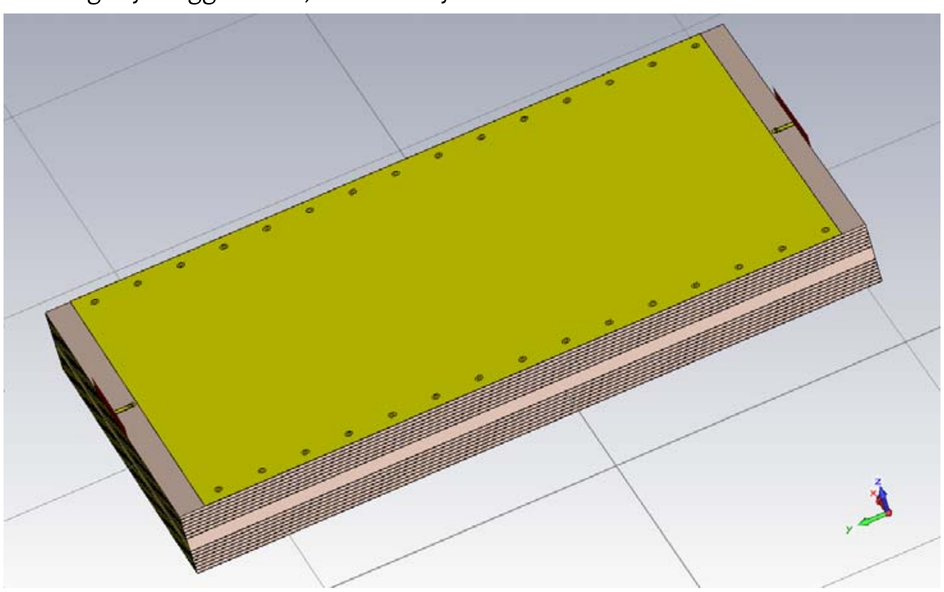

Figure: A 16 layer board with a stripline trace on layer 2

The Model:

So to understand the point where back drilling looses its necessity, I constructed a 16 layer, 4.64mm thick PCB filled with ground layers and just one stripline trace running on layer 2. The trace originates as a microstrip on layer 1, goes through a via, that needs to be back drilled and then continues on layer 2 for 44.8mm after which it comes back to layer 1 through another via, which also needs to be back drilled and finally terminates itself using a suitable impedance termination.

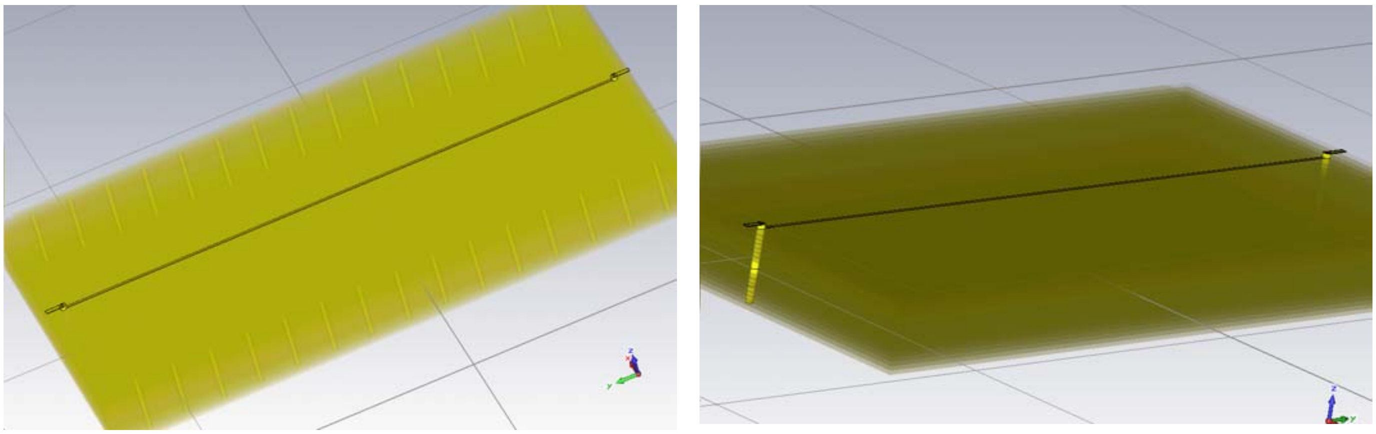

Figure: Set-up without via stub (Left) Set-up with via stub (right)

To start with, I simulated the reference structure with a via running from layer 1 to layer 16 that is not back drilled and constructed an eye diagram to understand how the signal would look after it reaches its destination. The eye diagram assumes a signal with rise and fall times of 50ps and a pulse width of 300ps. As you can see the eye is completely distorted and no useful information will reach from the source to the destination if the via was left as it is.

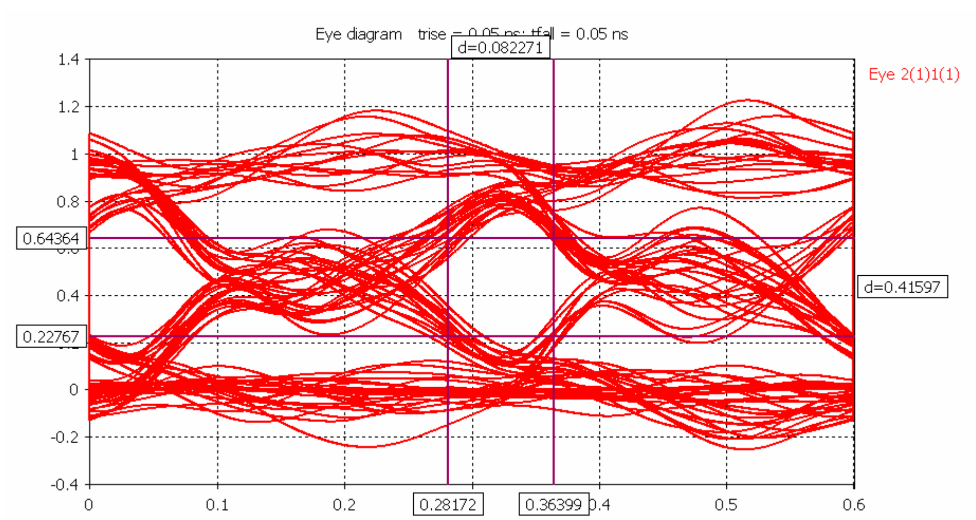

Figure: Eye Diagram with a 4.35mm (170mil) stub

Then, I simulated various back drilled via stub lengths and below are the simulated eye diagrams. As the via stub gets smaller, the eye width and height gets bigger meaning a better transmission from the source to the destination. The eye diagram gives an excellent idea how the signal integrity improves as the stub length is reduced. Almost all eye parameters get better as stub length is reduced.

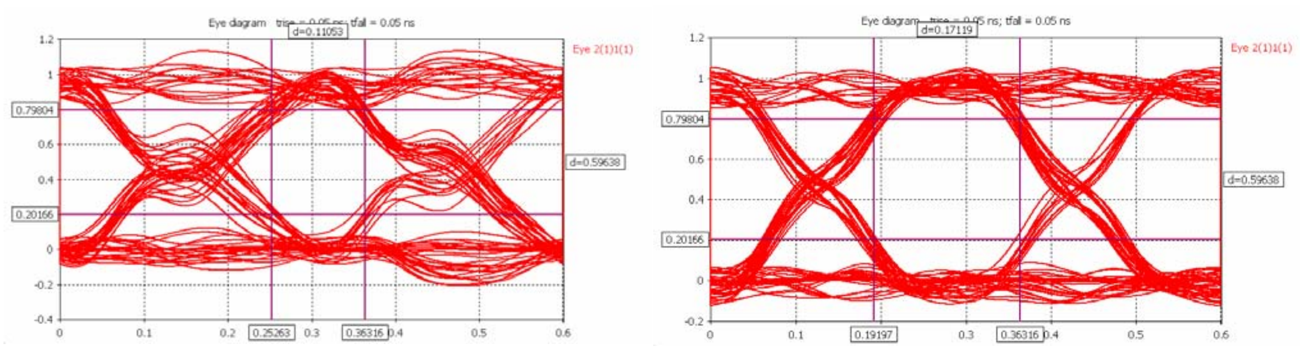

Figure: Eye Diagram with a 130mil stub (left) with a 90mil stub (right)

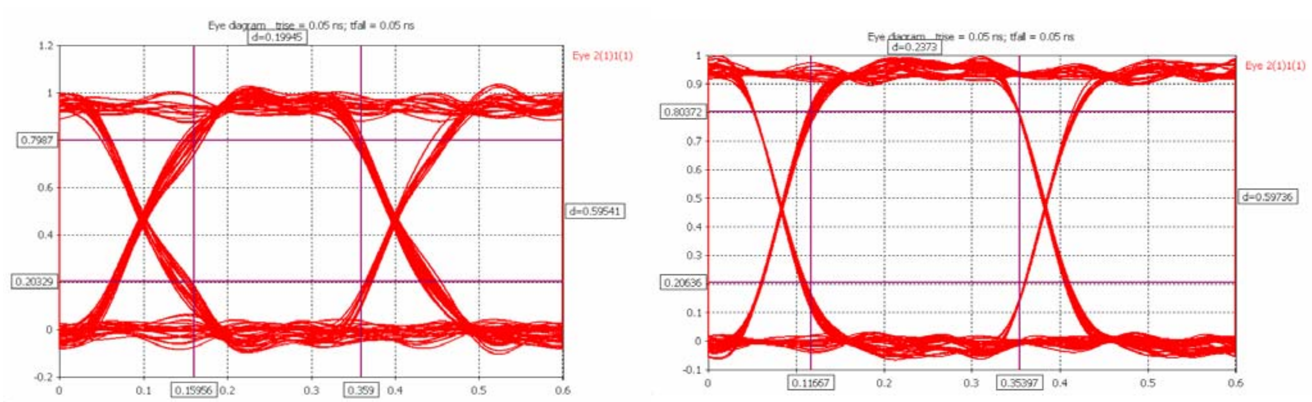

Figure: Eye Diagram with a 53mil stub (left) with a 30mil stub (right)

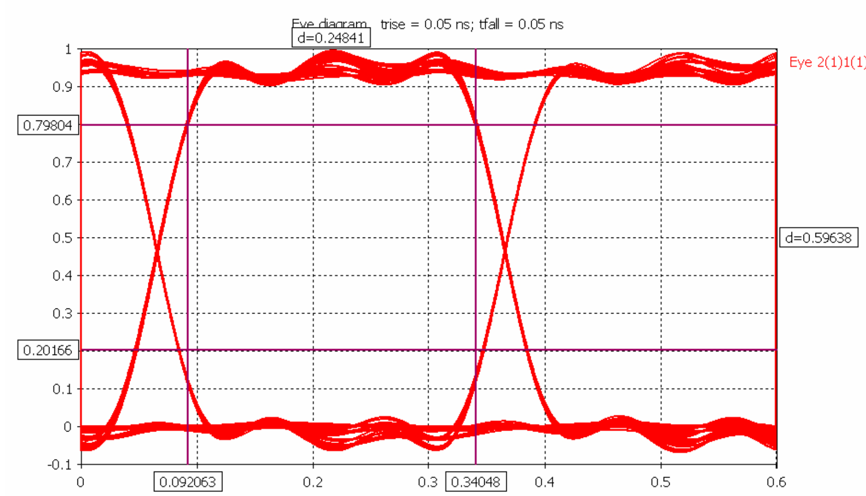

Figure: Eye Diagram with no stubs

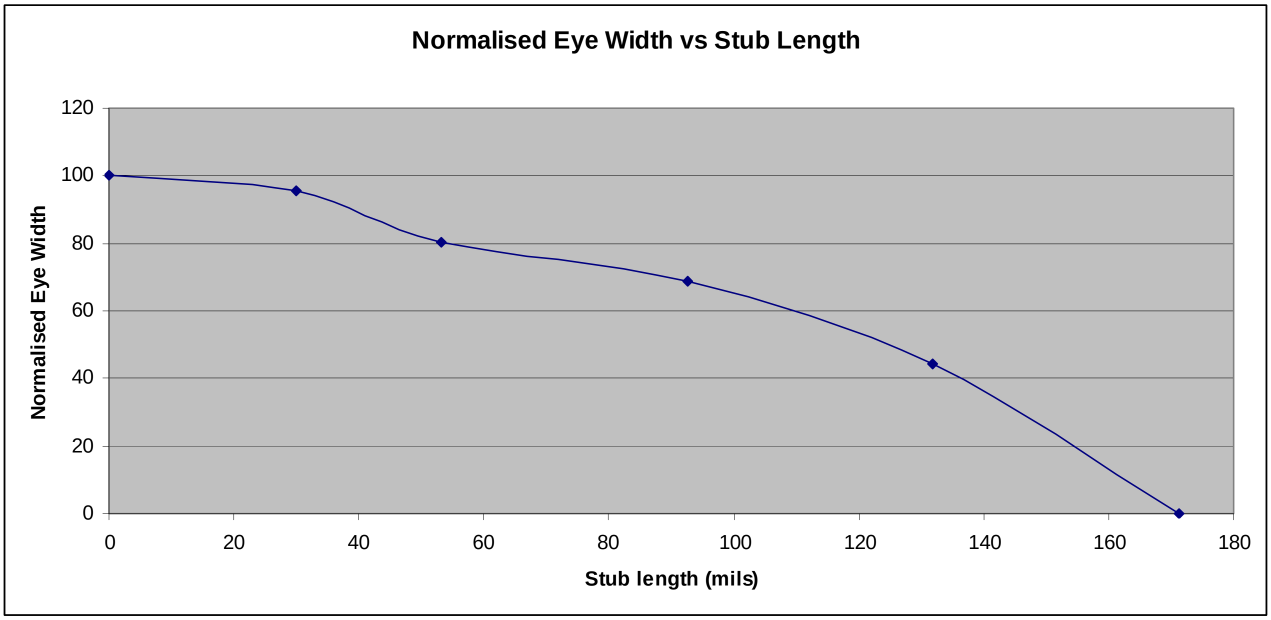

Figure: Normalised Eye Width Vs Stub Length

As can be seen in the graph above, the maximum normalized "usable" eye width (eye width measured between 20% and 80% of the signal) for a 300ps wide pulse (not including rise and fall times- just the pulse high time) is around 250ps, considering 50ps rise and fall times. About 80% of this maximum eye width can be achieved by back drilling the via to a stub length of around 53mils and about 90% by back drilling to a stub length of around 40mils.

The reflections that occur as a result of the via stub are eliminated and the impedance variations are much lower as the via stub length is reduced, even though there is a discontinuity in the trace as it moves from a microstrip to a stripline.

Conclusion:

From this observation, it looks very clear that zero stub length is the best possible solution. But our initial question was to find the solution that would provide the best value, in terms of signal integrity and cost. From a signal integrity point of view, if we say achieving 80% of the maximum achievable eye width is sufficient, then we can get away with stubs of around 50 to 55mils. At this stub length, the eye diagram with a rising edge of 50ps (equates to a frequency content of approximately 7GHz) looks very usable, which could be the solution that offers the best value! But if the frequency of interest is much higher then we will have to consider smaller stub lengths that could offer the best value.