Emission pattern in Series Terminations

Karthik Raj Guruchandran
www.basebandhub.com

Terminations – What are they?

All of us are aware of "Maximum power transfer theorem". It states that, in order to transfer maximum external power from a source with finite internal impedance, the impedance of the load must be made the same as that of the source. So, in a real high speed circuit, ideally to obtain maximum power transfer, we would want the source impedance to match the load impedance. That said, we need to keep in mind that a high speed trace on a PCB has finite capacitance and inductance associated with it and hence would act as a load to the driver. So in order to get maximum power transferred in a high speed circuit, we need to match the impedances of the driver with the trace and with the receiver. This combination allows for maximum power to flow from the source to the destination without any reflections. But many drivers are built for a better drive strength and tend to have impedances of around 20 ohms while the receivers are designed with high impedance of around 1 Mega ohms. So how do we match these two completely different parties and get as much power delivered? Well, we use terminations. Terminations are electronic components (generally passives) that are used to tweak the source and load impedances to the same value as the trace and allow maximum energy to be transferred. There are many different termination configurations that engineers use – the most common being, Series, Parallel, Thevenin, RC and Diode terminations. If you are interested to know in detail about these termination configurations, refer to the article **"Termination techniques for high-speed buses"** by ***Karthik Ethirajan and John Nemec.***

Series Termination:

Series termination uses the concept of source side matching, were we try and add an extra resistor to match the driver impedance to the same level as the trace impedance. Considering 50 ohm trace impedance, we would have to add a 22 ohm resistor to match a driver with 28 ohm internal impedance (as shown in the figure below). Sounds easy, isn't it? Only if life was that simple! The series termination value is an approximate number as the driver has varying impedances at rising and falling transitions. So the termination value is a best possible approximate. Some designers just go for a 22 ohm or a 33 ohm without even bothering what the source impedance is. Many simulate the circuit!

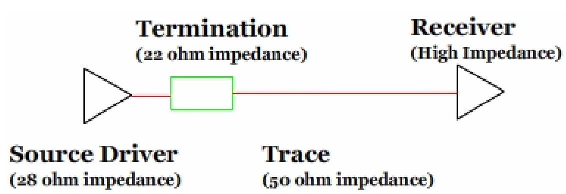

Figure: Design with a series termination

How Series termination works:

Series termination is used generally in energy conscious designs. Since the resistor is in series, there is very little wastage of power. To understand how the terminator works, we need to assume that a signal is driven by the source on to the trace. Since the source driver impedance + termination impedance equals trace impedance, only half the voltage appears on the trace. As the energy travels to the other end, it gets completely reflected (100% reflection) due to the high impedance receiver and that reflection causes the receiver to see double the voltage which is the original driven voltage. The reflected energy, however travels back to the source and gets absorbed by the 50 ohm impedance.

Emissions and Series terminations:

Near field emissions from a micro strip line using series terminations can be understood by simulating the trace in a 3D EM simulator. As we now know, the series termination works on 100% reflection from the receiver. So when a signal is driven, whose wavelength is significantly higher than the trace length, down an impedance matched trace, the near field peak formed around the trace is much lower. The reason behind this phenomenon is that when the wavelength is much longer than the trace length, the driver starts seeing reflected energy even before the entire original signal has been driven. In this case, most energy is burnt in the series termination and the source driver and hence the field associated at the source end is dense.

Let us consider an example. A signal with a frequency of 200 MHz travels on a microstrip trace with a propagation speed of 6.25 in/ns. So the wavelength of the signal would be

$\lambda = c/f$,
where,
λ is the wavelength,
c is the speed of electrons,
f is the frequency of interest.

So,	λ	=	6.25 / 0.2
		=	31.25 inches
		=	794mm
and	$\lambda/2$	=	397mm.

When I simulated this signal down a 50.8 mm (2 inch) trace, I could see that as soon as 1/28th of the wave was sent down reflections started moving in the other direction.

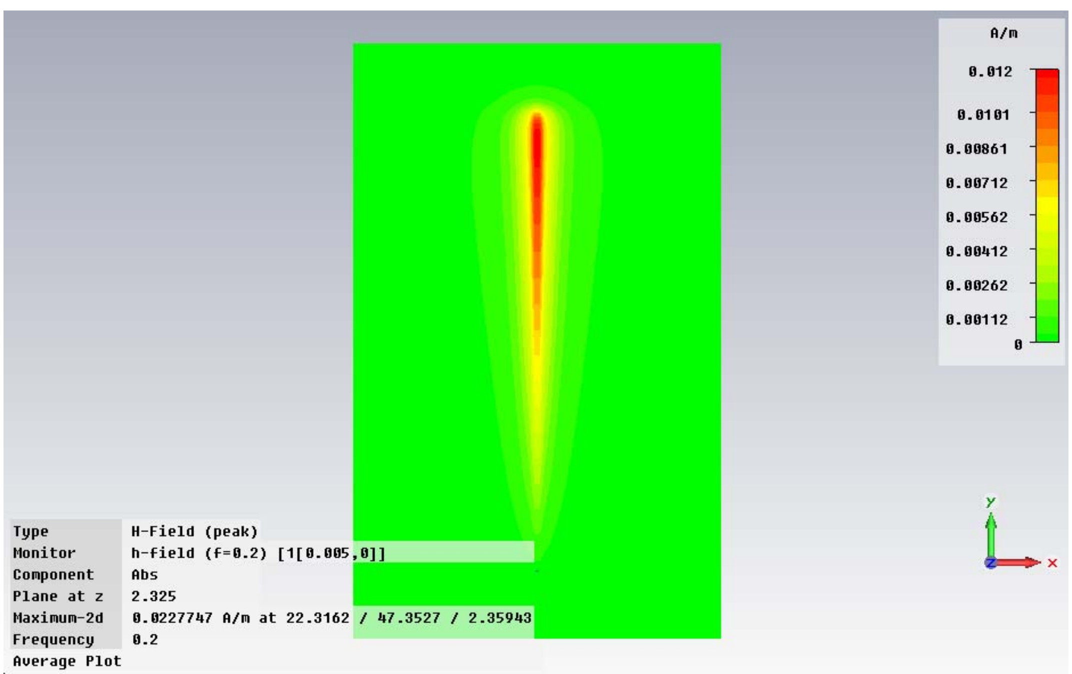

Figure: Near field from a micro strip with series terminations at 200 MHz

As the frequency increases, more energy is transmitted for the same trace length as the wavelength comes down causing more fields to be associated with the trace. This can be seen when a 1GHz signal is driven down the same 2 inch trace.

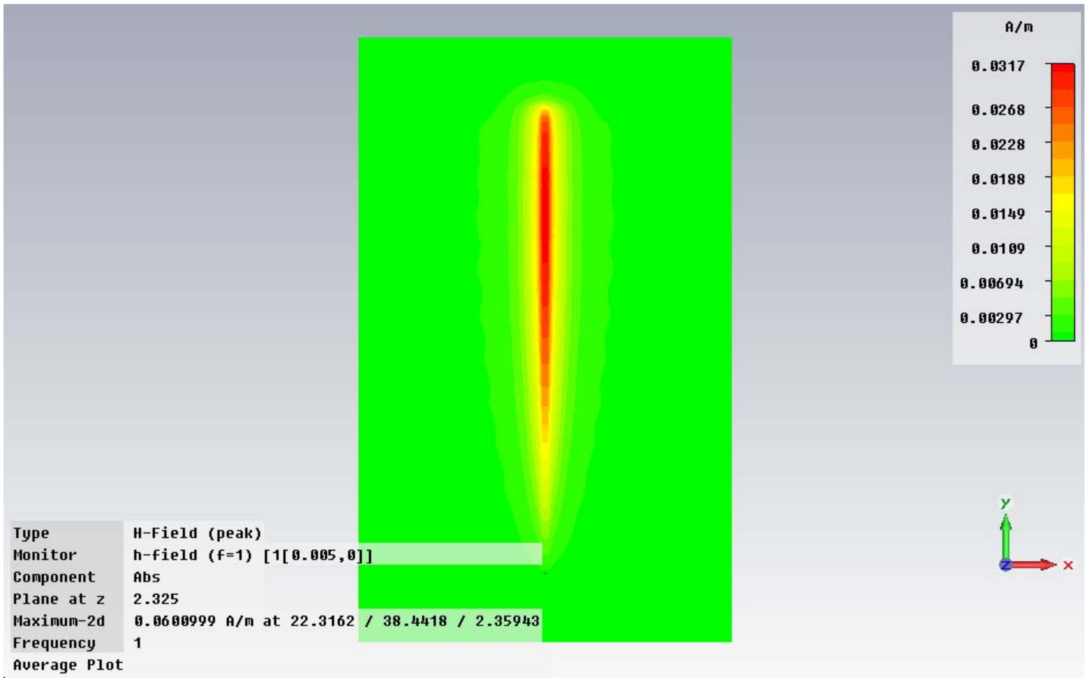

Figure: Near field from a micro strip with series terminations at 1 GHz

Continuing on these lines, the next obvious question is what happens when the wavelength is lesser or equal to the trace length? Where the trace length matches wavelength, a standing wave gets formed and the emissions associated with the trace have clear crests and troughs along the trace. The emission peaks are very similar to that of the frequency where a crest was driven down the line.

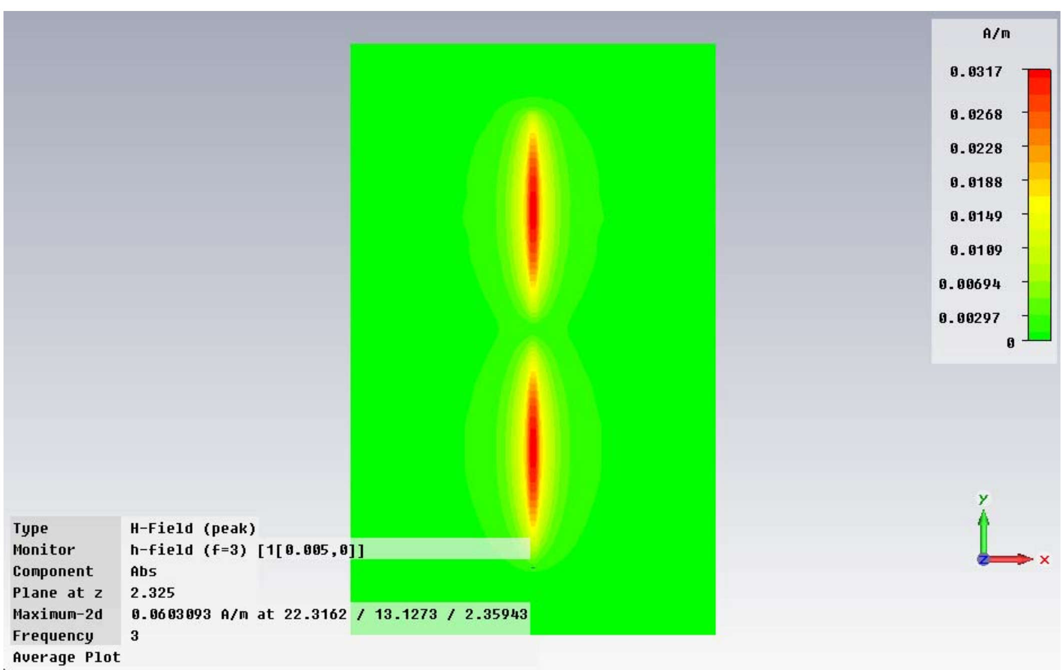

Figure: Near field from a micro strip with series terminations at 3GHz

Conclusion:

Emissions from a series termination depend on the frequency of interest and the trace length. Designs with very high wavelength to trace length ratios enjoy much lesser near field emissions when compared to designs that have unity or low wavelength to trace length ratios.

Signal Frequency (GHz)	Near Field (dBm)
0.2	-39.68
0.5	-26.8
1	-22.8
3	-22.7
5	-24.6

Table: Near field from a micro strip with series termination