TRACE BENDS:
Their impact on near fields (and EMC)

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Abstract:

This article is about trace bends on PCBs and its potential impact on near fields and EMC. Considering the complexity of the PCBs of today, it is impossible to have a trace without a bend on it and continuing with this trend we will have to use bends more often than before. Hence in this article, I have tried explaining the effect of a bend on near fields and I have considered bends with various angles and have formed a relationship between the variations of the associated near fields with respect to the variation of the bends.

Background:

There is a fair amount of data available in the electronics world that says PCB traces with 90 degree corners (bends) do a lot of harm and I think an equal number of theories that counter argue this theory and say that they are perfectly harmless. One particular article that impressed me was from **Mr. Douglas Brookes - 90 Degree Corners: The Final Turn** [1]. In that he had constructed PCBs with various trace bends on a microstrip configuration and then performed two logical experiments - one to measure the impedance discontinuity on the traces with and without bends and the other to measure Emissions from the traces at a distance of 1 metre. The reason behind measuring the impedance discontinuity is that, at bends the traces have a slightly different dimension (see figure 1 below) which mean the impedance at that point will be different (This can be measured using TDR method). After an extensive study, the conclusion was that the bends do not make any difference on both of the observed phenomena i.e. Impedance discontinuity and Emissions and hence having a bend on the PCBs is decisively harmless.

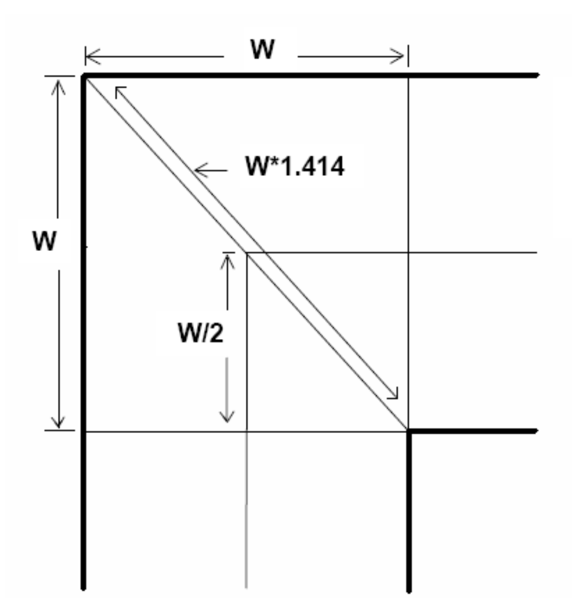

Figure 1: Structural Geometry of a trace bend

Reactive or Radiative:

I was convinced with the conclusion until I started working on Near Fields a few years ago. So to understand more about the jargons involved, let us step back a bit and understand the two different types of fields that exist in this world. One of them is called a Reactive field and the other is called a Radiative field. These fields, although both are electromagnetic, have different properties associated with them. The Reactive fields are near fields and are not lossy fields but instead store energy that is associated with the circuit within the field. So whenever a charge accelerates, the Electro-Magnetic fields get formed around the accelerating charge and they store the circuit's energy which can be transferred to another nearby circuitry on certain conditions causing energy loss to the source. To be more precise, let us assume a Transformer with an alternating input in one of the coils - which eventually produces an EM field (reactive field) around it. When the secondary coil is bought near the primary coil, this reactive field couples to the secondary coil and creates a voltage and current on the coil with the same frequency as the primary coil thereby transferring energy on to it. This energy transfer is not because the primary coil radiates energy which was picked up by the secondary coil but because the secondary coil was within the vicinity of the primary coil. These fields are near fields and they have different characteristics than the far fields. So, when energy transfer occurs it leads to a loss in the energy in the source side.
The radiating fields on the other hand are associated with a circuit due to the circuits' construction and dimension and can be compared to a resistor which has a definite loss associated with it. One can imagine a constant value resistor connected to a voltage source and no matter what happens, the resistor will continue burning energy as heat without the influence of any other circuitry. So, the radiating fields are not dependent on what is near it and will exist independent of any loading circuitry. The fields just keep 'radiating' until it gets absorbed eventually by something somewhere. It is this radiating field that generally a cause for concern for EMC issues when they start to interfere with other equipments or electronics components near by and might force them to malfunction.

Near to Far Coupling:

So if we can measure the far field (radiating fields) from a PCB trace and prove that they are not strong enough to interfere with the operation of any other electronic circuitry then that proves that the dimensions of the trace (whether it has bends or not) does not have any impact on the EMC performance – and that was clearly shown on the article **90 degree corners: The Final Turn.** But what about the near fields associated with these traces? What if they are stronger when the traces bend? What if the near field (reactive field) couples itself to a nearby electrically long cable or trace and then that cable or trace starts radiating in the far field?

Test Set-up:

To understand and analyze more about this, I constructed 4 different microstrip traces of 50 ohm impedance each in a 3D simulation environment. The software package used was CST Microwave Studio. The configurations of the traces were as follows:

Trace 1: Straight Line with no bends or turns

Trace 2: Trace with a 90 degree bend

Trace 3: Trace with a 135 degree bend

Trace 4: Trace with a 45 degree bend

After meshing the structure sensibly enough, I then simulated each trace separately with a waveguide port input. After making sure the simulation runs as intended, I calculated the near field (H-field) at 1mm above the trace to see what the simulated field strength looked like at the length of the trace.

Results:

The results were as suspected – the near field was definitely stronger near the bend and was more pronounced than any other point in the trace (see figure 2).

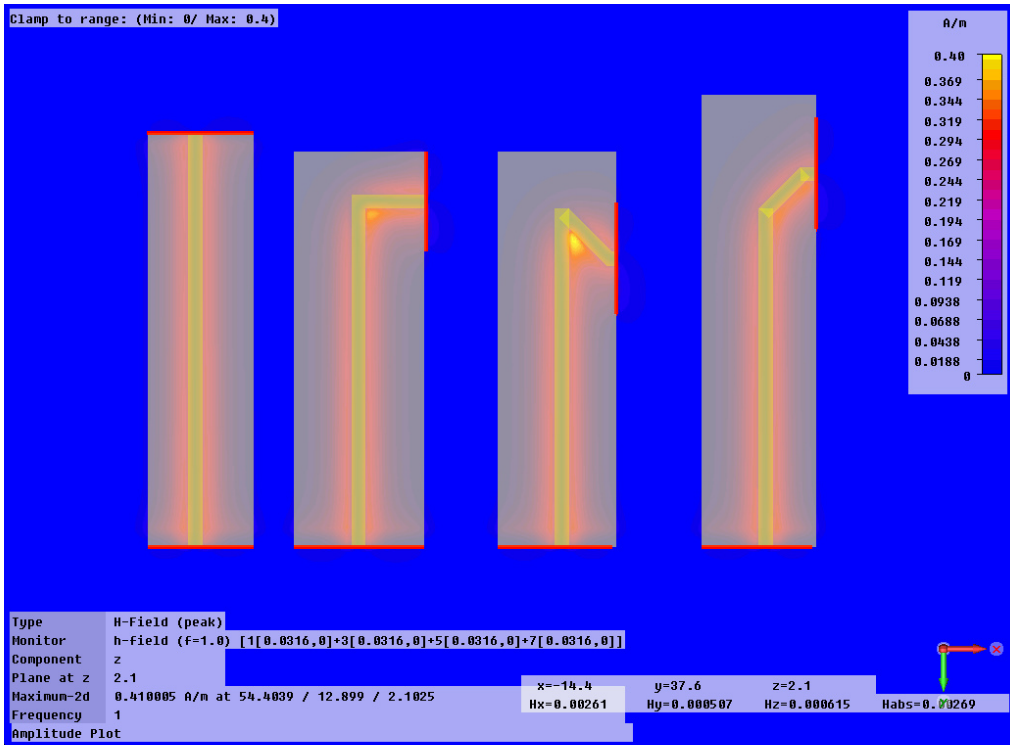

Figure 2: Simulated Near Fields associated with a trace bend

What was further more interesting was that the field strength associated with the near field increased progressively with Bend angle. Plotting the field strength with bend angle provided a nice 'close-to-linear' response and I was able to see around 4-5dB difference for every 45 degree change in the bend of the PCB trace. In practical cases, there can be many electrically long traces that would be within 1 mm of other traces and will easily pickup this strong field and transfer them outside the PCB as radiated fields.

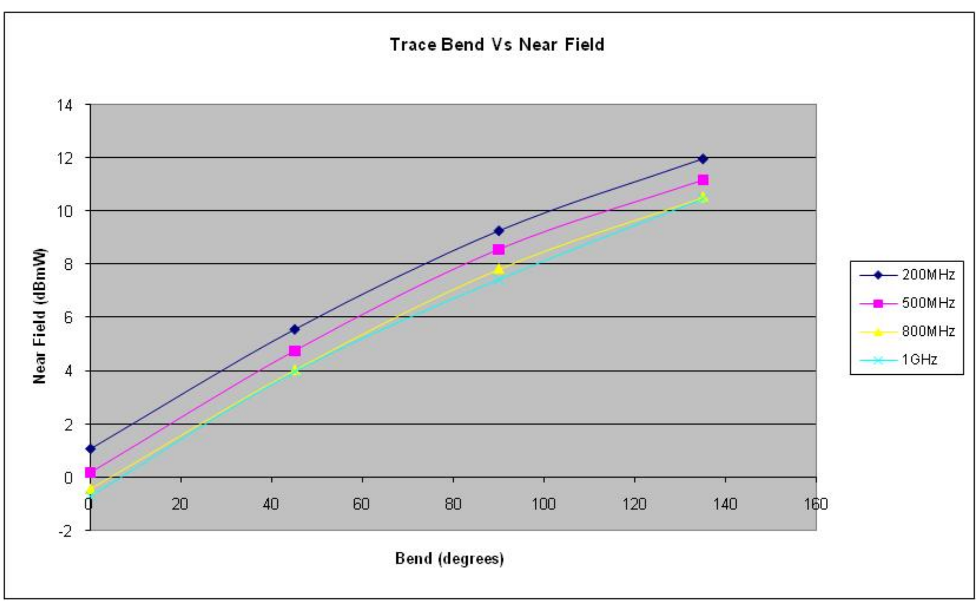

Figure 3: Near Fields variation with bend angle

Near field and EMC:

To understand how much of the energy associated with the near field will be picked up by a potential antenna; we need to know the coupling co-efficient between the bend and the trace that runs next to it. If we also know the energy that is radiated from the trace then one can deduce the real effect of the bend on far fields and EMC. One important point to remember – This impact on near field will vary on a case by case basis as it is directly associated with the trace spacing and trace dimensions of those routed nearby that can potentially emit and cause interference.

Conclusion:

To conclude, it appears that bends and corners on PCB traces have a definite effect on EMC and emissions but it depends on the traces that are routed next to them. If there are long traces that have a potential to radiate and are routed right next to bends then there is more likely an opportunity to have an EMC problem. In my next article, I will write about crosstalk and coupling between traces. So watch out!!!

References:

1) http://www.ultracad.com/articles/90deg.pdf