



## **Effects Of Corners In PCB Traces**

A novel SPICE simulation technique was developed to investigate the effects of corners in PCB traces. The PCB traces were modeled by breaking them down into tiny squares or finite elements. A SPICE sub-circuit was made for the finite element and a small square symbol with one pin on each face was also created for it. Many such symbols were then placed in a schematic (like tiles) to graphically and electrically represent a PCB trace. A comparison was then done between a straight trace, one with a 90 degree square corner, and another with a 90 degree corner beveled at 45 degrees.

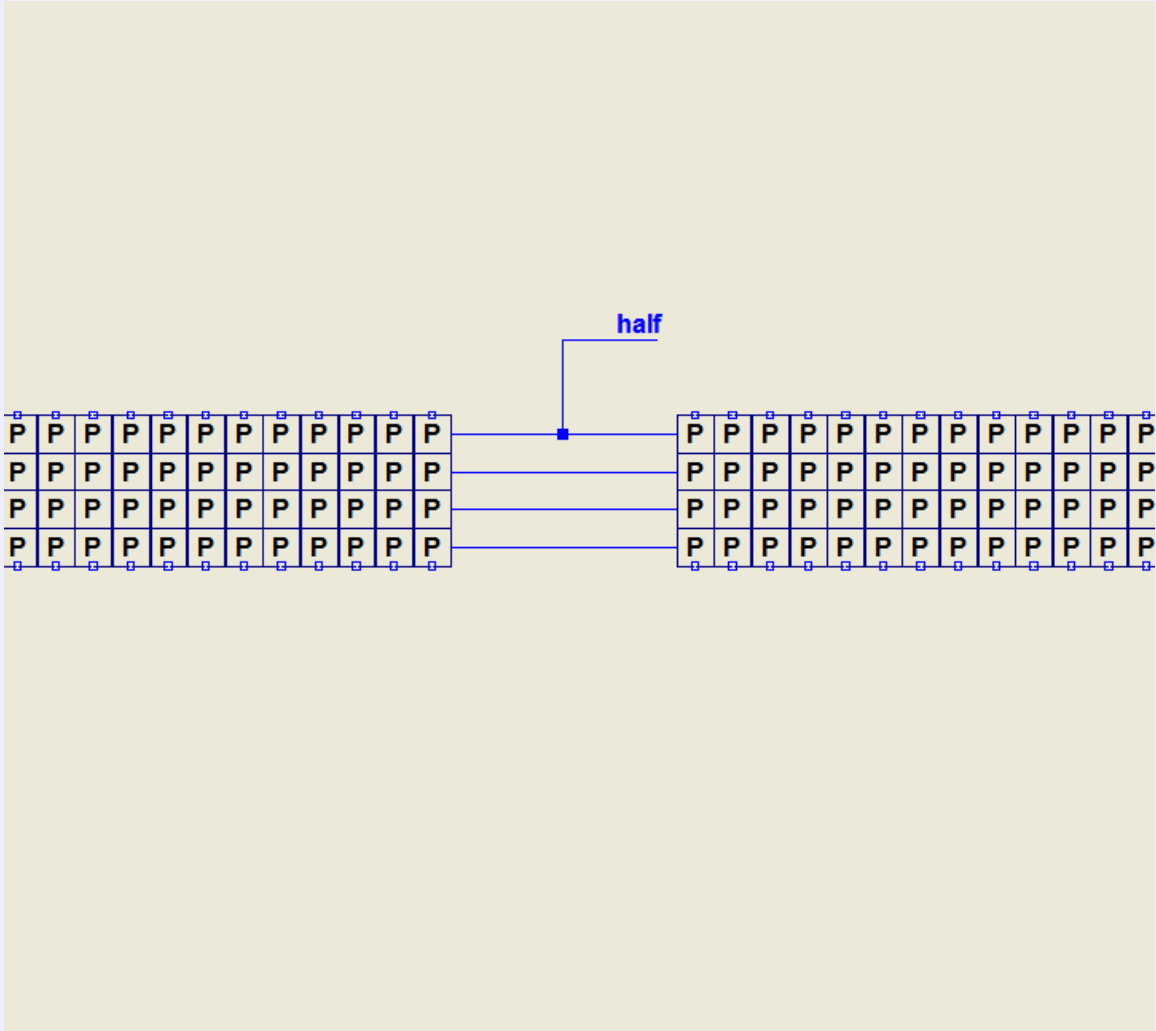
The results show that there is a very small but detectable effect due to the corners. When injecting a 1 V pulse with an extremely fast rise time of 10 ps, a small perturbation was seen in the waveform on the order of 10's of millivolts that lasts for 10's of picoseconds. This is due to a few femtofarads of extra capacitance at the corner because the trace is 1.414 times wider there. Similar results were reported in [1].

If the corner is beveled at 45 degrees by cutting diagonally across the square of the corner, this appears to cause a perturbation in the opposite direction – since the trace now gets 0.707 as wide at the corner. It is believed that a trace drawn with a round aperture would result in the correct rounding of the corners to avoid perturbation however round corners could not be exactly simulated using this method. Many PCB design software tools can draw traces with rounded corners.

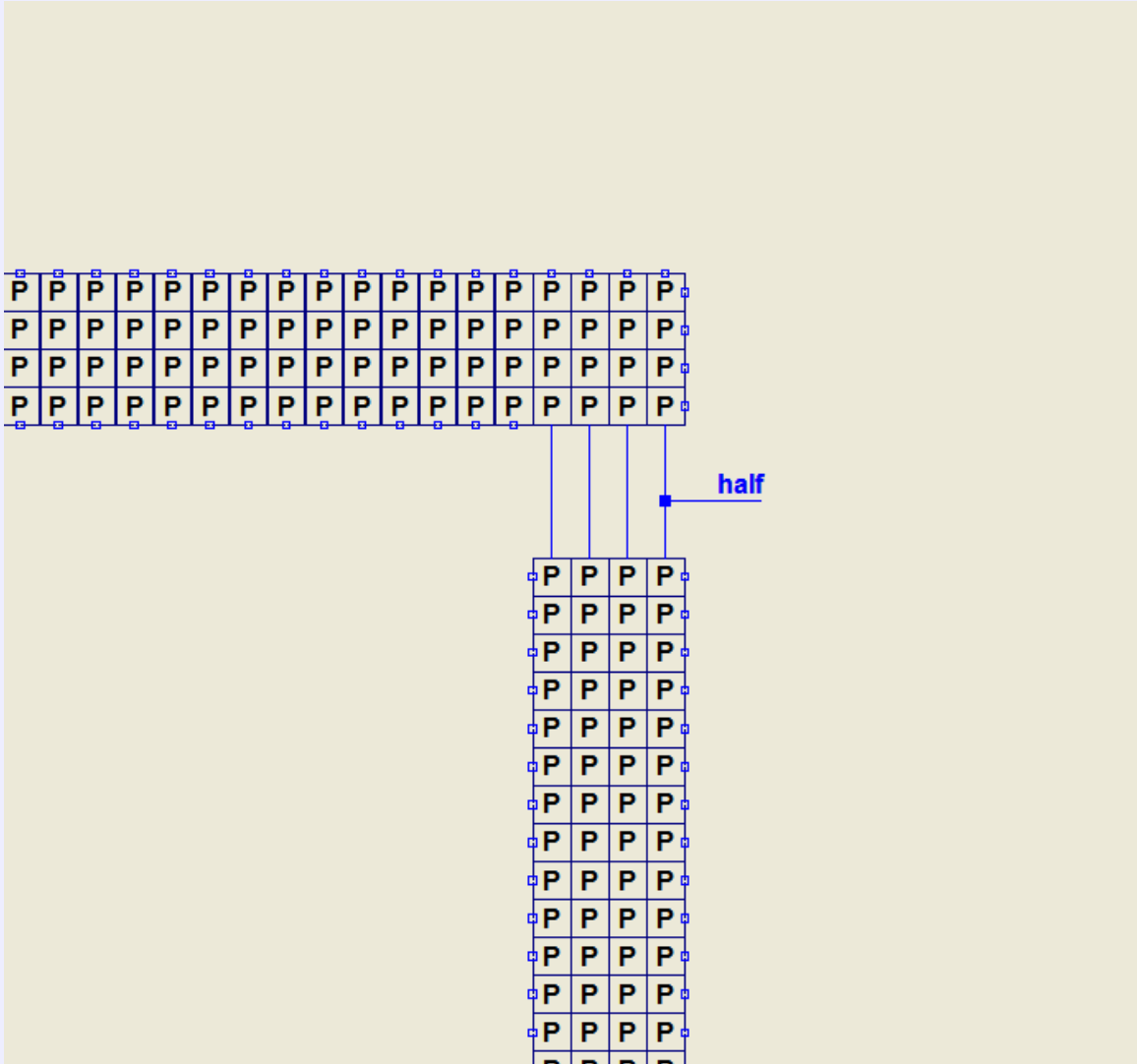
In conclusion, there can be a very small signal perturbation at corners, but it is due to changes in trace width, not the fact that the wave has to change directions. The small magnitude and duration of the effect shown here allow one to decide if it is truly an issue for a given application.

[1] OLL-116 Separating Myth From Reality in Signal Integrity, Eric Bogatin,  
<http://www.BeTheSignal.com>

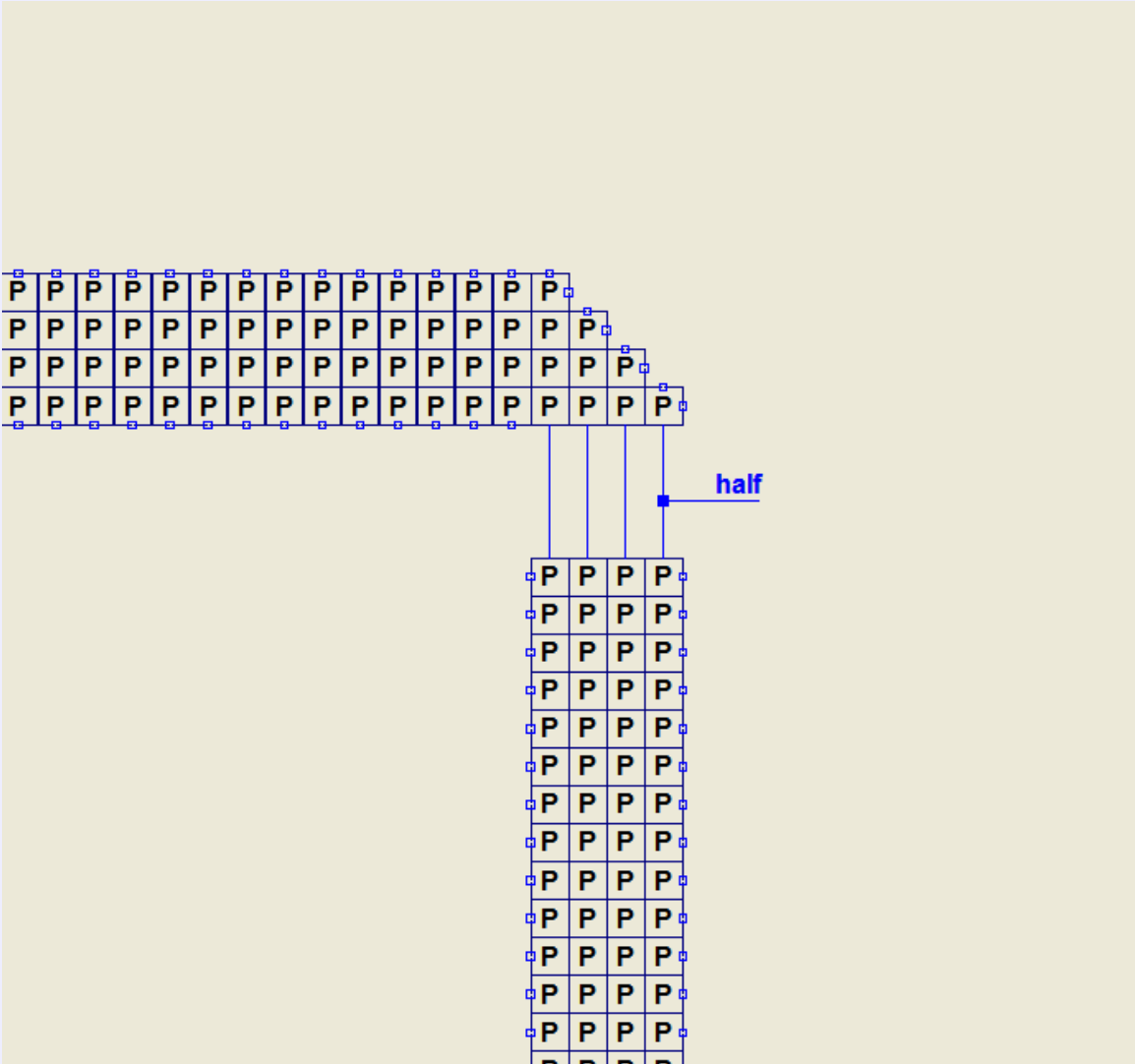




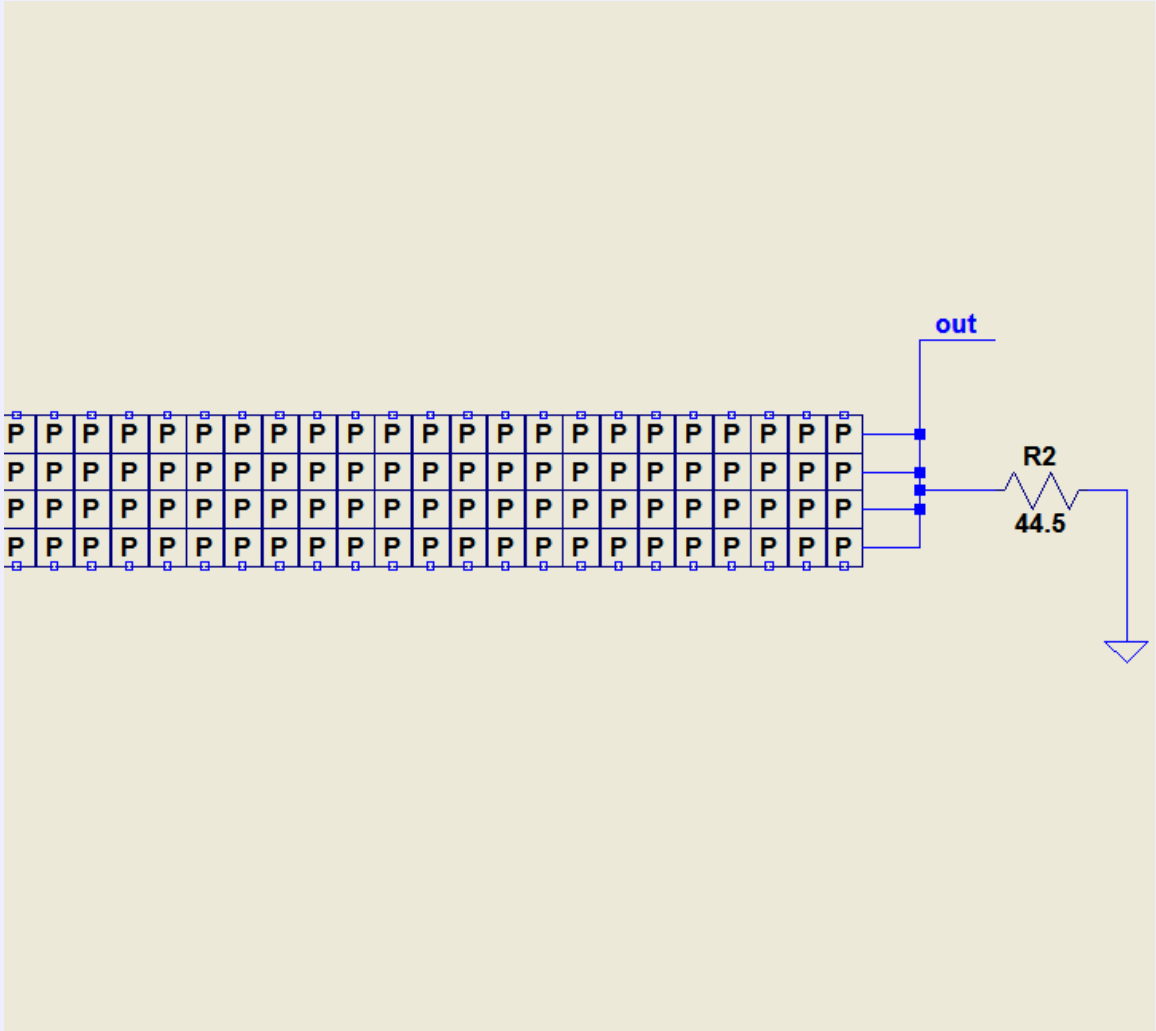
Trace model at the midpoint (for a straight trace).



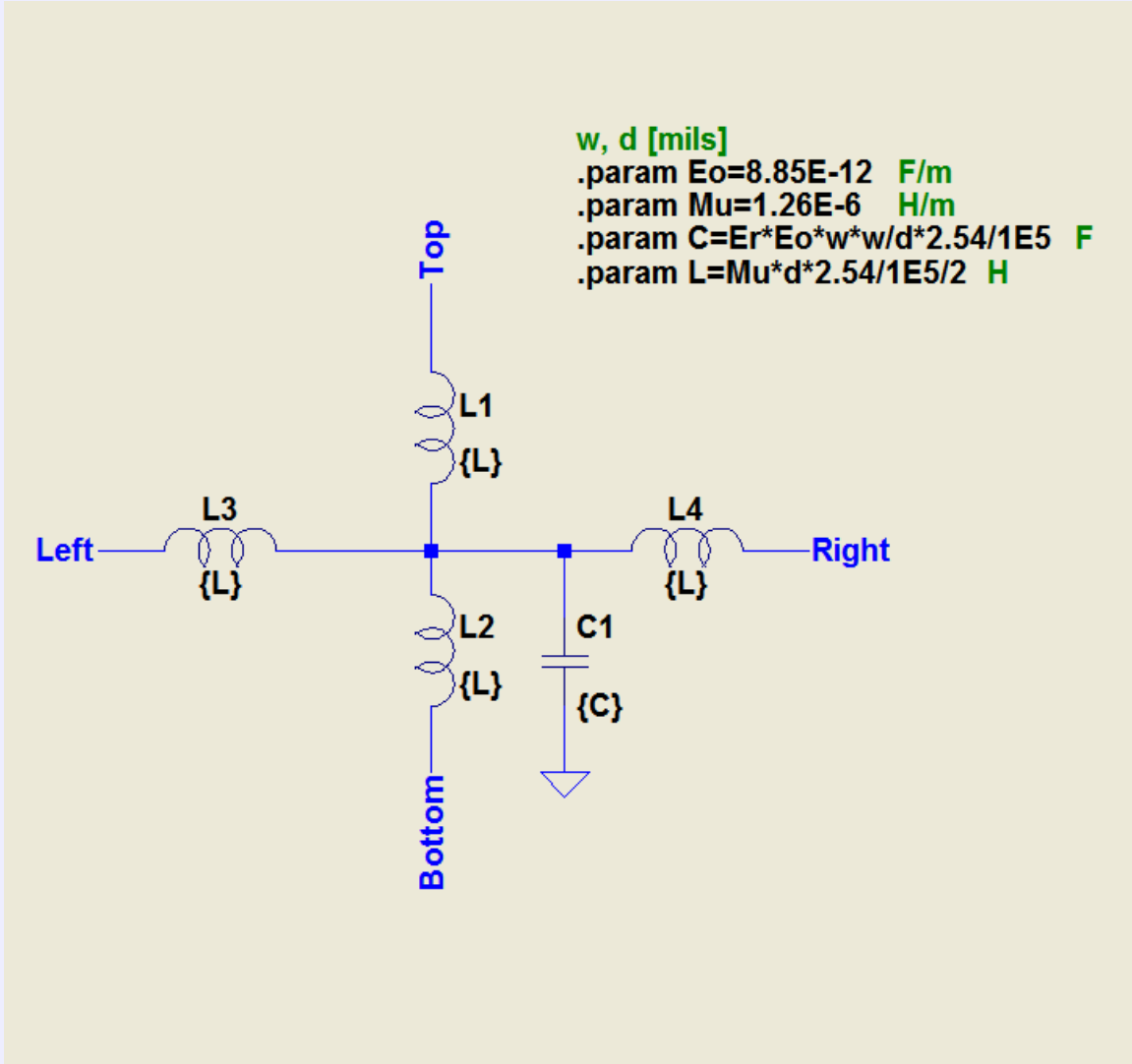
Trace model at the midpoint (for a 90 degree square-cornered trace).



Trace model at the midpoint (for a 90 degree beveled corner trace).



Trace model at the load end.



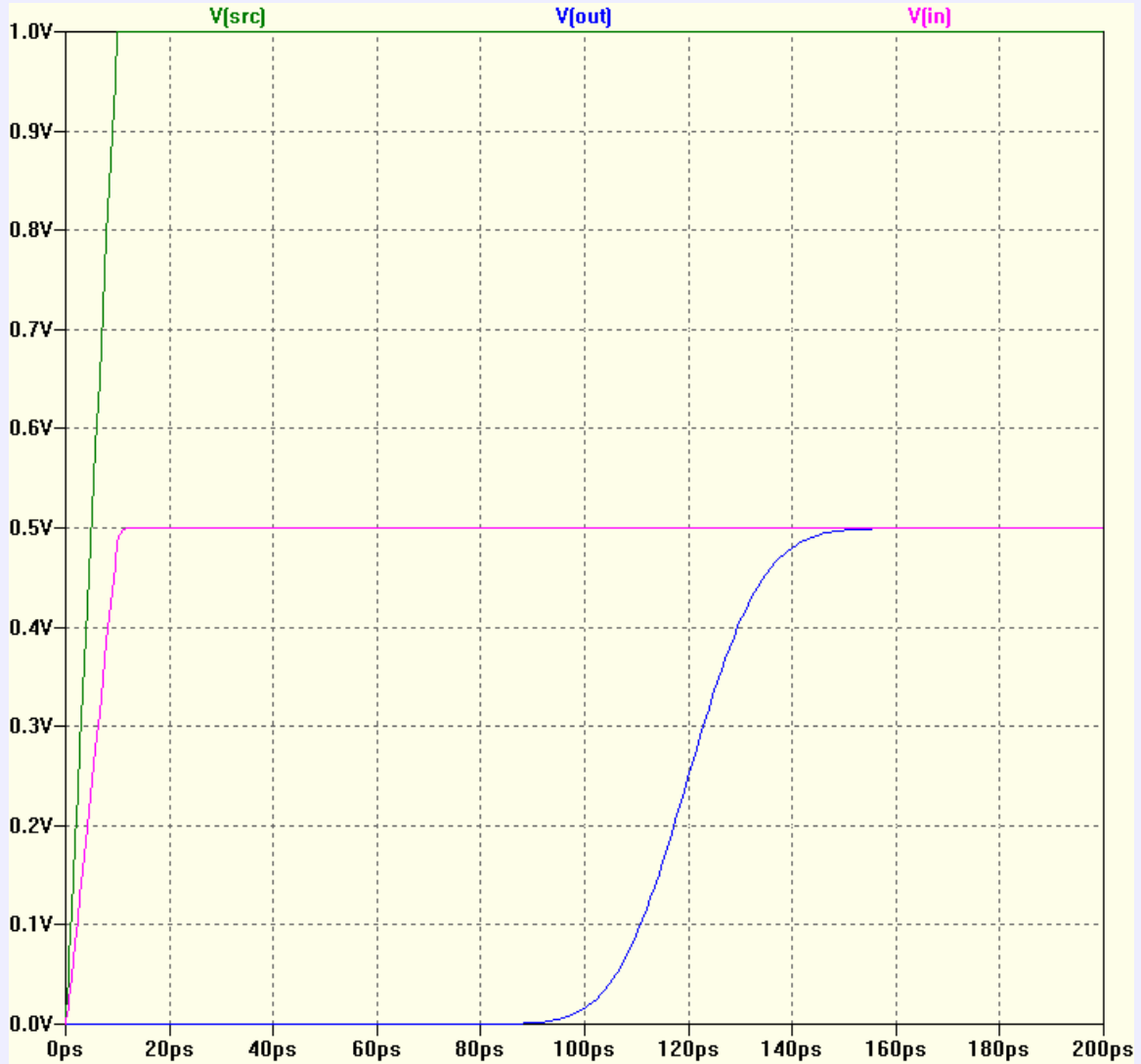
Sub-Circuit model of a finite element of PCB trace.

Parameters passed to model:

w = width (and length) of copper square [mils]

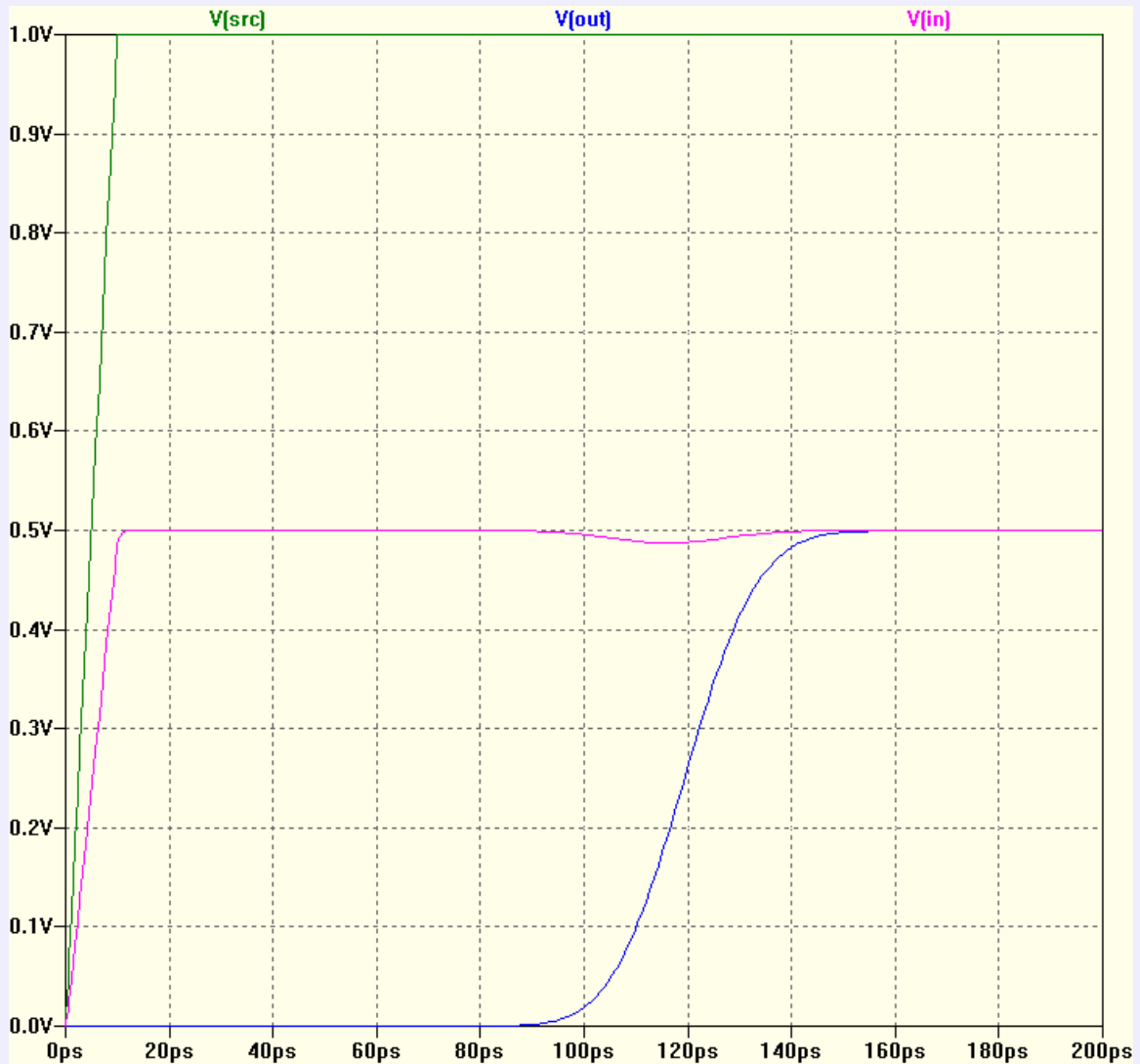
d = distance above ground [mils]

Er = relative permittivity (dielectric constant) of PCB material

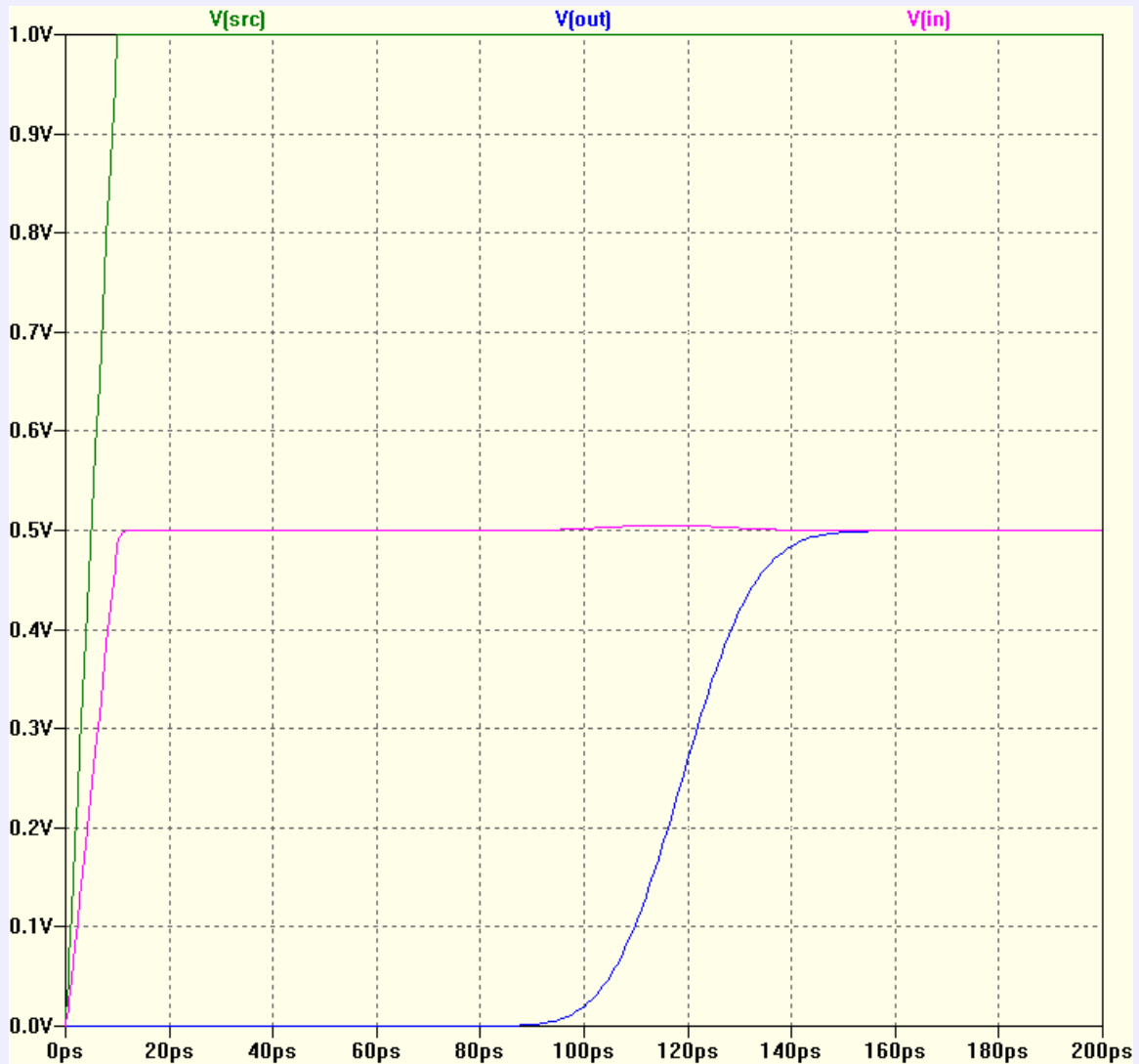


640 mil long, 20 mil wide microstrip trace 5 mils above ground on an FR-4 board. The waveform arrives at the end of the trace in 120 ps. There are no perturbations seen in the  $V_{in}$  trace.





640 mil long, 20 mil wide microstrip trace 5 mils above ground on an FR-4 board. The trace has a 90 degree square corner at the midpoint. The waveform arrives at the end of the trace in 120 ps. A small downward perturbation is seen in the  $V_{in}$  trace near 120 ps which is the round trip time for the signal to go to the corner and back. The corner has slightly more capacitance (lower impedance) than the rest of the trace.



640 mil long, 20 mil wide microstrip trace 5 mils above ground on an FR-4 board. The trace has a 90 degree corner with a 45 degree bevel at the midpoint. The waveform arrives at the end of the trace in 120 ps. A small upward perturbation is seen in the  $V_{in}$  trace near 120 ps which is the round trip time for the signal to go to the corner and back. The corner has slightly less capacitance (higher impedance) than the rest of the trace.