



[Software tool fixes some causality violations](#)

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Causality is the way the real world works: a response can't come before its stimulus arrives. All real-world measurements must obey causality, but some S-parameter measurements seem to violate it. An S-parameter behavioral model with a causality problem, used in a circuit simulation, usually results in a prediction that is non-physical and just plain wrong.

The Root Cause

How is it possible for a measurement, or simulation, of an S-parameter behavioral model to show non-causal behavior and what can we do to prevent this problem?

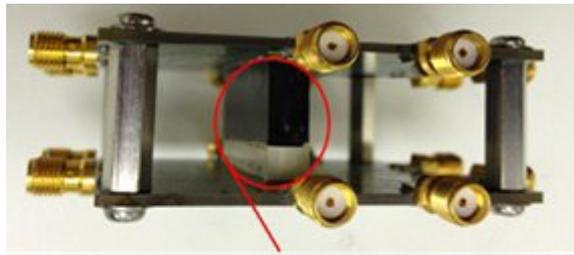
One common root cause of causality violations is from de-embedding. De-embedding is the process by which we take a measurement of a DUT we care about, with fixture or launch elements on either side, and extract just the DUT from the composite measurement.

After de-embedding, the reference plane of the measurement is moved to the beginning of the DUT. When the signal encounters the DUT, time = 0.

There are a number of de-embedding processes. [TRL](#) (thru, reflect, line) is historically the most common de-embedding process. All methods share one thing in common. The essential step is to create an S-parameter model for each fixture and use these models, with some matrix math, to calculate the S-parameters of just the DUT.

In a way, the fixtures are "subtracted" from the fixture + DUT + fixture measurement, leaving just the DUT measurement.

If the fixture models used in the de-embedding math are not exactly the same as the fixtures that are actually part of the DUT measurement, a "phantom limb" piece of the fixture can be "left behind" that occurs before the DUT. This means there is a response in the DUT model that happens before the stimulus: a causality violation.



Mezzanine connector (DUT)

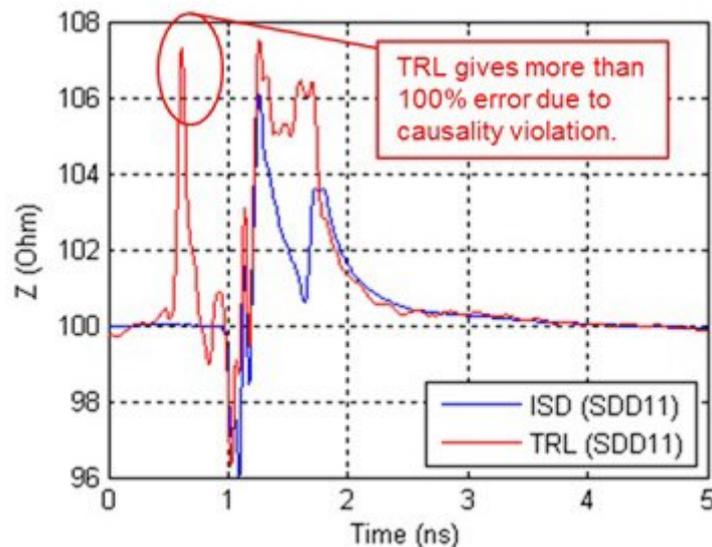


Figure 1 shows an example of the measured TDR response of a connector mounted to a board with fixture structures that were de-embedded using the TRL method, leaving behind a piece of the launch fixture before the signal gets to the connector.

One way to assure the fixture models used to de-embed the DUT really are the same as the fixtures attached to the DUT is to use ISD (in-situ de-embedding). This is when the measurement of the actual fixture attached to the DUT is used to create the de-embed model.

Ching-Chao Huang, the creator of the [Ataitec Software suite](#), told me that he coined the term "in-situ de-embedding" a number of years ago and the rest of the industry has adopted it. When I first heard the term, I liked it so much, I also started to use it.

The Ataitec Software suite includes a tool which will take the S-parameters of a [2x thru](#) and the fixture + DUT + fixture measurement and perform an in-situ de-embed to extract just the DUT.

When implemented correctly, ISD dramatically eliminates causality violations from de-embedding steps. In **Figure 1**, the ISD method eliminates this causality violation.