Anritsu envision : ensure

Distinction Between TRL and LRL

Although the TRL family of calibration algorithms have been around for over 40 years, there are still questions sometimes regarding differences between the family members. This is partially due to differences in various implementations over the years. The purpose of this document is to discuss some of the differences in the context of vector network analyzers (VNAs).

The original TRL work is often attributed to Engen and Hoer [1] where the standards consisted of a zero-length thru line (T), a reflect standard, and a non-zero-length line (L). In a later paper [2], they introduced the concept of LRL — where the first standard could be of arbitrary length but the line length difference rules (relative to the frequency range) applied between the two lines, just as they did between the thru and the line, in the original TRL. Importantly, since the intrinsic reference plane of TRL and LRL is in the middle of line 1, there really is very little difference algorithmically. Extracting from [2] in the section describing LRL:

> *The first four equations show that the four-port parameters .... are exactly equal to those obtained from the TRL solution. Equations (5) and (6) show that the four-port parameters a and α are scaled by $e^{\gamma_1 l_1}$ ....*

Here, l_1 is the length of the first line and γ_1 is the propagation constant. Eul and Schiek expanded on this concept slightly in a later paper [3]. Extracting from this paper in the section on Lxx (their generalization of LRL, while Txx is their generalization of TRL):

> *The calibration steps are performed as in Txx without any changes yielding the matrices ~~A and ~~B. Obviously the reference places will be located in the center of l_1.*

If one follows the approach of these authors in LRL and if the line 1 length is set to 0, the result is identical to that of TRL. In the case when line 1 length is not 0, then there is still no difference if the reference plane selection remains as "middle of line 1" since, from the instrument's point-of-view, these are the exact same configurations (assuming the user has entered relative line lengths correctly so that root choice is not impaired). If "ends of line 1" was selected as the reference plane choice, then there is an additional step where the reference planes are rotated back out (using knowledge of the propagation constant) as suggested by the sentence above from the paper by Eul and Schiek.

The various reference planes are illustrated in the Figure 1. The effective test ports are the green and yellow boxes, and the reference planes (with "middle of line1" selected) are shown with the red dashed line. In this implementation, the reference plane is always in the middle of the first standard so that in the limiting case of line1 length going to zero (with line length differences being maintained) the LRL case collapses to the TRL case.

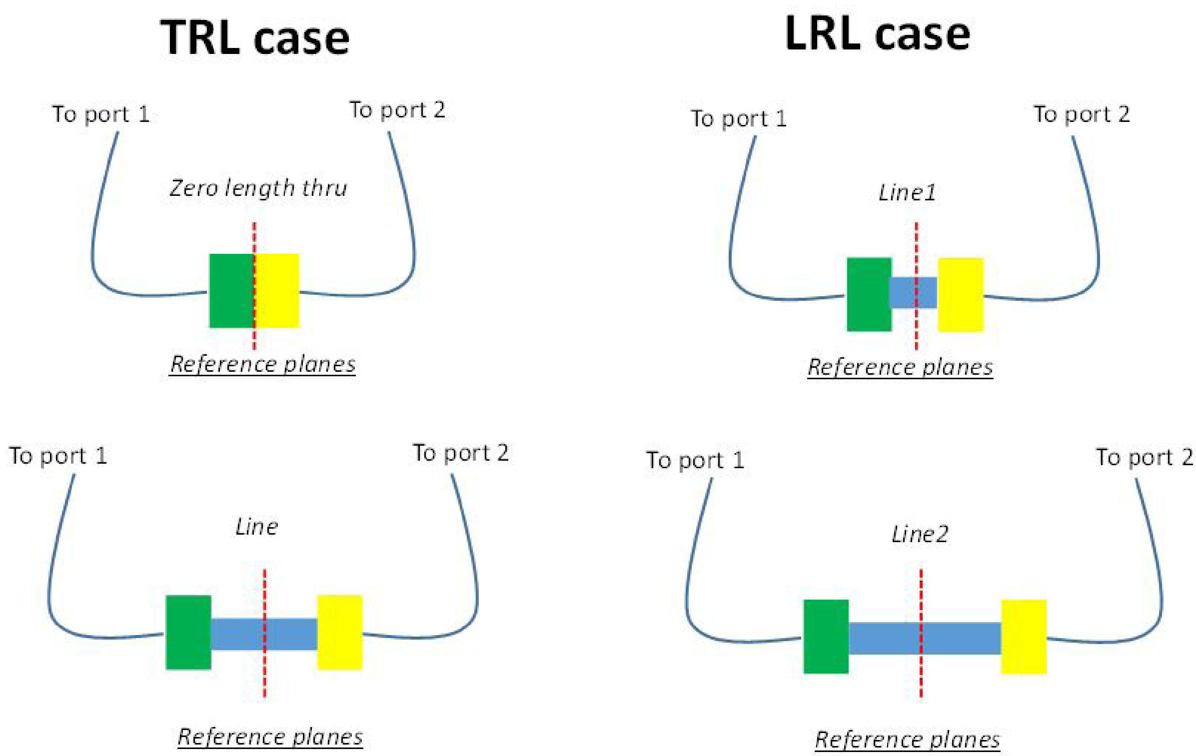

Figure 1. TRL and LRL cases with reference planes

The exact same concepts apply to TRM and LRM (the related calibration methods where a match standard replaces the second line). The algorithm intrinsically places the reference plane in the middle of line 1 so that when that line is defined to have zero length, LRM collapses to TRM in this implementation. Again, if the line length is not zero and if the reference plane selection is “ends of line 1”, an additional step of rotating out the reference planes is performed in LRM.

References

[1] G. F. Engen and C. A. Hoer, “Thru-reflect-line: An improved technique for calibrating the dual six port automatic network analyzer,” IEEE Trans. Micr. Theory Techn., vol. MTT-27, Dec. 1979, pp. 987-993.

[2] C. A. Hoer and G. F. Engen, “Calibrating a dual six-port or four-port for measuring two ports with any connector,” IEEE MTT-S Int. Micr. Symp. Dig., June 1986, pp. 665-668.

[3] H. – J. Eul and B. Schiek, “A generalized theory and new calibration procedures for network analyzer self-calibration,” IEEE Trans. Micr. Theory Techn., vol. 39, Apr. 1991, pp. 724-731.

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