Precise S-parameter measurements are the key to modelling electric circuits

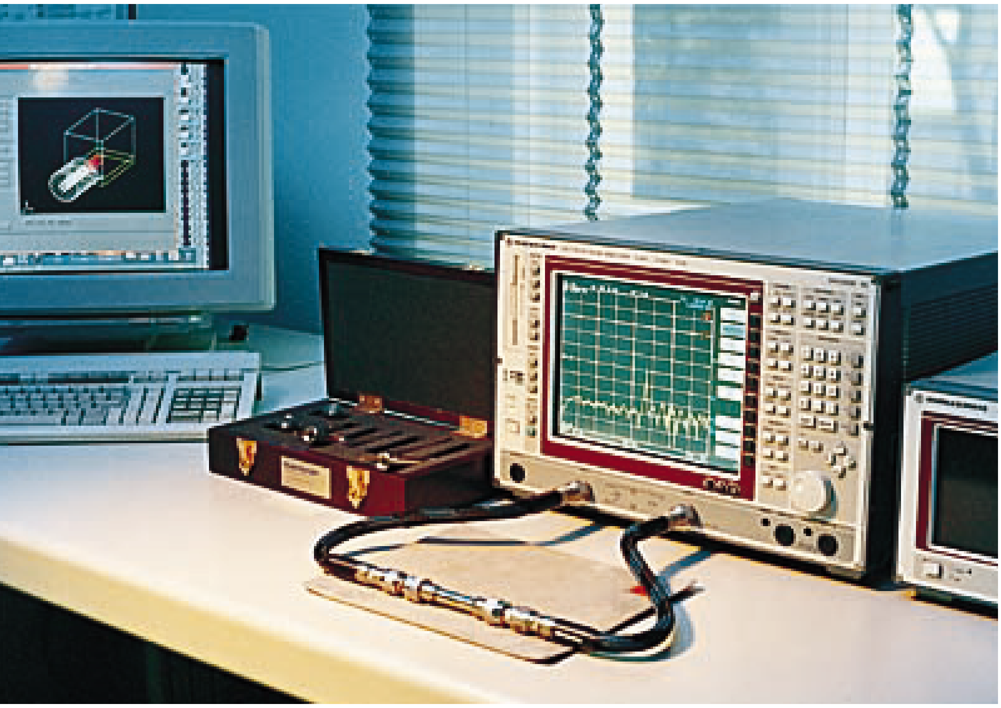

FIG 1 Vector Network Analyzer ZVR used by Rosenberger Hochfrequenztechnik
Photo: Schröck-Freudenthaler

High-precision S-parameter measurement is the basis for characterizing a circuit component. The outstanding measurement accuracy of **Vector Network Analyzer ZVR** from Rohde & Schwarz [1] offers the possibility of efficiently modelling well-matched DUTs. Precision measurements call for ultra-modern calibration techniques and high-quality calibration standards along with excellent hardware.

All modern network analyzers claim very high measurement accuracy since the S-parameters are displayed with an extremely flat frequency response. Unfortunately, this is a fallacy as precision measurements still call for sound background knowledge. The need to calibrate a vector network analyzer as precisely as possible is illustrated by the following simple example: a well-matched DUT (return loss 20 dB) is to be measured and modelled. To carry out this task to approx. 0.8 dB or 5° accuracy, the analyzer must have a directivity of more than 40 dB. In this case, matched loads cannot be used as calibration standards since their return loss is not sufficient.

Only precise lines can be used as impedance standards for such measurements. ZVR supports the use of lines with **calibration technique TRL** (thru, reflect, line) [2]. Besides direct connection of the two test ports and a precise reference line, this technique requires a reflection standard whose S-parameters need not be known. These calibration standards can be produced very precisely in both planar and coaxial line systems. Difficulties with the TRL technique occur if the line has a length of n $\cdot\lambda/2$. In this case, the line shows the same electric characteristics as the through-connection which leads to dependent equations for the corrective parameters. The following results show, however, that this only plays a minor role in practice.

To determine the measurement accuracy of Vector Network Analyzer ZVR in the frequency range from 10 MHz to 4 GHz, a high-quality coaxial PC7 air line from **Rosenberger Hochfrequenztechnik*** was employed for calibrating the ZVR.

In different verification measurements using the precision PC7 line system, the 63.5 mm long **air line** behaves like a T standard at lower frequencies and around 2.36 GHz:

$$f = \frac{c_0}{2 \cdot n \cdot 63.5\ \text{mm}}\ ; \quad n = 1.$$

As already mentioned, the TRL technique does not call for a known reflection standard. Reflection standards

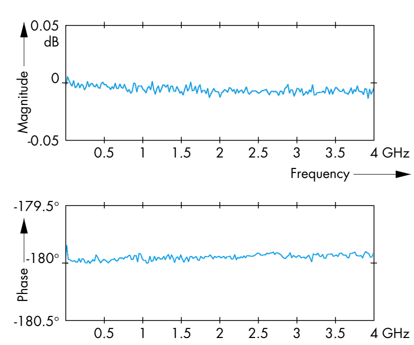

FIG 2 Reflection characteristic of short after TRL correction in Vector Network Analyzer ZVR

* The company based in Upper Bavaria was founded in 1958 and has become a leading manufacturer of coaxial connectors and test equipment for high-frequency applications.

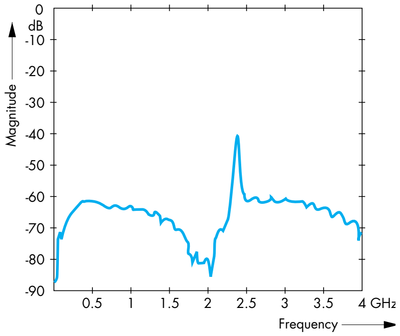

FIG 3 Reflection characteristic of second air line after TRL correction in ZVR

with the same electric characteristics have to be measured at both test ports during calibration. For the "sexless" PC7 system, this requirement can be met with high precision since the same standard can be contacted at both analyzer test ports (FIG 1). Therefore, the calibration standard requirements of TRL technique are almost perfectly met. The only shortcomings are the finite reproducibility of contacts which are better than –70 dB for PC7, the phase stability of the test cable (0.1° short-time stability for precision cables) and the deviations from ideal air-line geometry values. The latter are around 2 µm and limit the return loss of air lines to approx. 60 dB.

Shorts can also be produced as precisely as air lines. Since a **precision short** in the TRL technique is never used as a calibration standard, it is good for verification. FIG 2 shows a TRL-corrected reflection measurement of a short. Given the small deviations of the reflection measurement of 0.01 dB and 0.1°, ZVR can be concluded to have an effective matching of more than 55 dB after system error correction [3].

This excellent matching value can also be determined directly through the measurement of a **second air line.** This measurement is thus ideal for verification since narrowband effects such as the (n $\cdot\lambda/2$) errors can be analyzed very precisely. It can be seen that matching drops to 30 dB at 2.36 GHz (FIG 3). The consequences of limited measurement capability at 2.36 GHz are illustrated by FIG 4 which shows the verification measurement of a 25 Ω precision air line used as DUT. The result – just like that in FIG 3 – also shows that the ZVR measurement accuracy is extremely good at 10 MHz although measurement is very close to 0 $\cdot\lambda/2$.

A very popular verification measurement is the **ripple test** [4] in which a 300 mm long precision air line terminated with a short is measured (FIG 5). Calibration with opens or shorts of finite goodness shows instead of a linear curve a clear superimposed ripple which is twice the attenuation of this long air line. This ripple also helps to make conclusions regarding network analyzer matching. The ripple invisible here attests the excellent quality of the ZVR hardware.

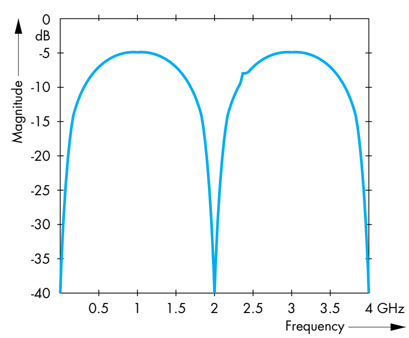

FIG 4 Reflection characteristic of 25 Ω air line after TRL correction in ZVR

Excellent quality of the hardware and system error correction software of ZVR is confirmed by all four verification measurements performed in the precision PC7 line system to analyze the measurement accuracy of Vector Network Analyzer ZVR after TRL calibration. The minimal errors found can be fully attributed to the finite performance data of the calibration elements, verification elements and test cables. Thus, ZVR is an ideal platform for modelling electric circuits and components to an accuracy of a few degrees.

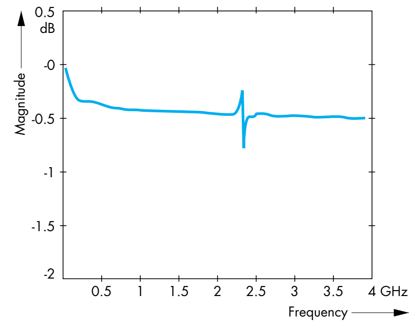

FIG 5 Reflection characteristic of 300 mm long air line terminated with short after TRL correction in ZVR

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REFERENCES

[1] Ostwald, O.; Evers, C.: Vector Network Analyzer Family ZVR – To the heart of the chart. News from Rohde & Schwarz (1996) No. 150, pp 6–9

[2] Engen, G. F.; Hoer, C. A.: Thru-Reflect-Line: An Improved Technique for Calibrating the Dual Six-Port Automatic Network Analyzer. IEEE Trans. MTT-27 (Dec. 1979) No. 12, pp 987-993

[3] Rohde & Schwarz: Measurement uncertainties for vector network analysis. Application Note 1EZ29_0E (Oct. 1996)

[4] Rosenberger: Streuparametermessungen in koaxialen Leitersystemen. Application Note TI020/26.07.96/D1.0 (July 1996)

Reader service card 156/08 for further information on ZVR