

Some typical values for the residual error terms of a calibrated vector automatic network analyser (ANA)

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Abstract

This paper gives some typical values for the residual error terms associated with a calibrated vector automatic network analyser (ANA). The residual errors are assessed using the currently accepted methods. The values can be used as a guide to the likely size of residual errors found on other ANAs. Such values are often included in an overall assessment of the uncertainty of measurement for an ANA.

1 Introduction

In recent years, methods have been evolving for the efficient evaluation of the post-calibration residual errors in vector ANAs. Of these methods, the so called 'ripple technique' has gained much popularity and now forms the basis for a full evaluation of the uncertainty of measurement for an ANA [1]. The method is suitable for vector ANAs operating at microwave frequencies, and is in line with current national [2] and international [3] guidelines for evaluating and expressing the uncertainty in measurement.

There is, however, only sparse documented information on the typical performance of this evaluation technique when applied to measurements made using precision coaxial connectors. This paper provides further information for some of the more popular precision connector types, *i.e.* those used with 7 mm and 3.5 mm 50 ohm coaxial lines. The effects on these error terms due to using different schemes to calibrate the ANA are also considered. In each case, the residual directivity error term, D , and residual test port match error term, M , are evaluated using the method given in [1].

2 Calibration details

2.1 Different connector types

In the first instance, a short-open-load technique was used to calibrate the ANA. In the case of the load standard, a lowband fixed load was used for frequencies up to 2 GHz. A sliding load was used above 2 GHz, with the sliding load element set to six different settings. This was considered to be an acceptable number of settings for the ANA's calibration algorithm to perform satisfactorily.

The above calibration scheme was implemented each time after configuring the ANA for measurements using three different connector types, *i.e.* GPC-7, type-N and GPC-3.5. In the case of the GPC-7 and type-N configurations, the ANA was calibrated from 1 GHz to 18 GHz. For the GPC-3.5 measurements, the upper frequency was extended to 33 GHz. The measuring instrument used to make all the measurements was an HP 8510C ANA fitted with a 40 GHz S -parameter test set (type HP 8516A).

To assess the terms D and M , the following artefacts were connected to the ANA immediately after calibration:

- a length of precision 50 ohm reference air line of the appropriate diameter terminated with a well-matched load. The maximum adjacent peak-to-peak ripple gives an indication of the maximum residual directivity error over the chosen frequency range;

$$D = (\text{Maximum adjacent peak-to-peak ripple}) \div 2$$

- the same reference air line terminated with a short-circuit. As before, the maximum adjacent peak-to-peak ripple gives an assessment of the maximum residual test port match error over the chosen frequency range;

$$M = (\text{Maximum adjacent peak-to-peak ripple}) \div 2$$

The length of precision reference air line was achieved using the 50 ohm line section found in commercial ANA verification kits, being of lengths 100 mm, 125 mm and 75 mm for the GPC-7, Type-N and GPC-3.5 connector types, respectively.

2.2 Different calibration methods

A subsequent investigation examined the effects on the size of the residual errors due to performing different types of ANA calibration. The following three types of calibration were evaluated:

- (i) Short-Open-Load using a lowband load below 2 GHz and a broadband load above 2 GHz;
- (ii) Short-Open-Load using a lowband load below 2 GHz and a sliding load above 2 GHz (as before);
- (iii) Thru-Reflect-Line using a short-circuit as the Reflect device and a line of nominally 7 mm in length as the Line standard.

This investigation was confined to just the GPC-7 connector type, as it was felt that any trends observed with this connector type would be similar to trends exhibited by the other connector types.

3 Results

The results obtained for the residual error terms for the different connector types using the Short-Open-Load (including sliding load) calibration technique are shown in Table 1. (Note, all values given in the tables are rounded to one significant figure.)

A typical plot obtained during the residual directivity error assessment is shown in Figure 1. Similarly, Figure 2 shows a plot obtained during the residual test port match error assessment. Both plots were made when the ANA was configured for type-N measurements.

The results obtained for the different calibration methods implemented in GPC-7 are shown in Table 2.

	Residual directivity, D	Residual test port match, M
GPC-7	0.002	0.008
Type-N	0.005	0.007
GPC-3.5	0.004	0.008

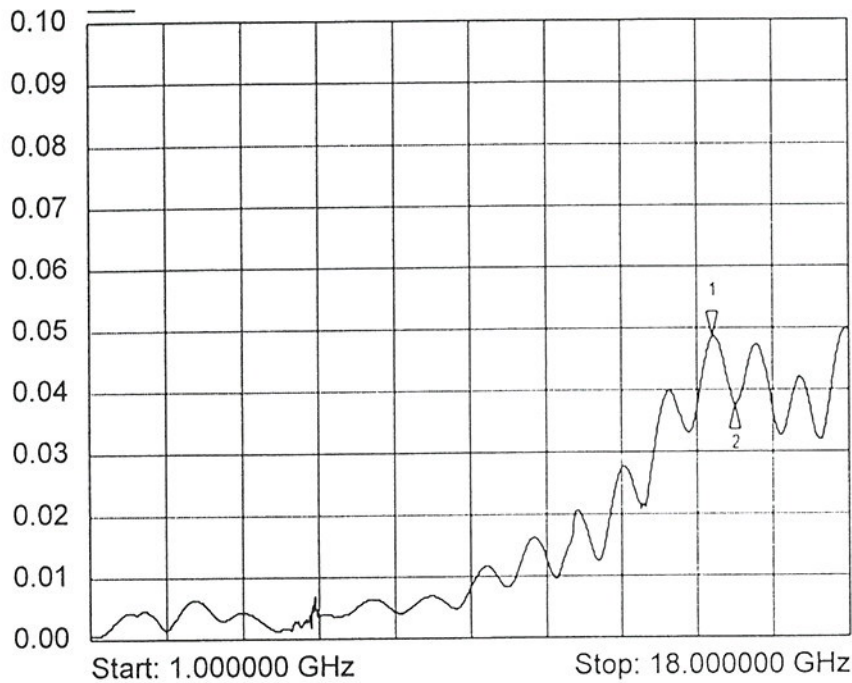
Table 1: typical values for the residual error terms achieved for the different coaxial connector types

	Residual directivity, D	Residual test port match, M
Short-Open-Load	0.01	0.03
Short-Open-Load (including sliding load)	0.002	0.008
Thru-Reflect-Line	0.001	0.001

Table 2: typical values for the residual error terms achieved using different calibration methods

Figure 1: Residual directivity error assessment for the type-N calibration

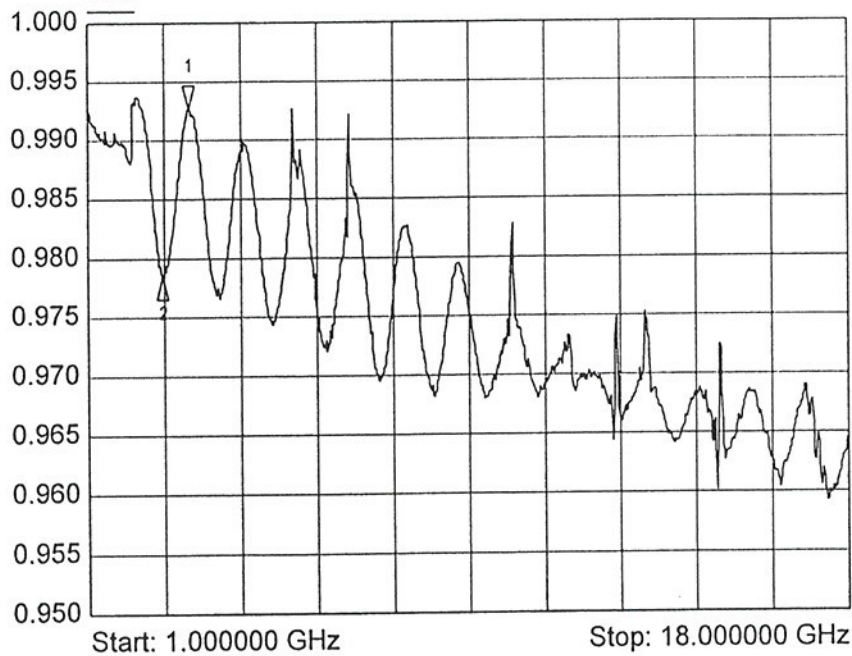
Lin
S11



1	14.948167 GHz
▽	48.5906 mLin
2	15.463970 GHz
▽	37.6442 mLin

Figure 2: Residual test port match error assessment for the type-N calibration

Lin
S11



1	3.235145 GHz
▽	992.6787 mLin
2	2.676359 GHz
▽	978.5579 mLin

Observations

The values produced for the residual error terms show some interesting trends. Firstly, for the investigation into the effects of using different connector types (Table 1), the M values are generally larger than the D values. There is not a great deal of variation in the values as the connector type is changed: ranging from 0.002 to 0.005 for D ; and, from 0.007 to 0.008 for M .

However, there is much greater variation in the residual error terms when different calibration techniques are used (Table 2): ranging from 0.001 to 0.01 for D ; and, from 0.001 to 0.03 for M . Clearly, the TRL calibration yields the smallest residual errors, followed by the Short-Open-Load (including sliding load) technique, then the Short-Open-Load (using fixed loads) technique. This ranking of the calibre of these calibration schemes agrees well with microwave metrology folklore for ANAs.

A further observation relates to the interpretation of ripple plots when assessing the residual directivity error. The ripple trace is often superimposed on the trace for the response of the load terminating the reference air line. This can be seen in Figure 1, where the response begins to rise significantly above approximately 8 GHz. In such cases, the ripple response needs to be 'de-embedded' from that of the terminating load. This can be achieved either by eye, or by using the electrical delay facility found on most modern ANAs [4].

Finally, it is worth mentioning the occurrence of several 'spikes' on the trace shown in Figure 2. These spikes should not be interpreted as part of the ripple for the trace. They are likely to be an indication of localised calibration instability at certain frequencies and are probably caused by ill-conditioning of the ANAs sliding load algorithm.

Conclusions

This paper has presented some typical values for the post-calibration residual errors for a vector ANA. The values show that, for the connector types considered here, the sizes of the residual error terms are very similar. However, the sizes do depend significantly on the type of calibration technique used with the ANA. TRL calibrations produce the smallest residuals, followed by the Short-Open-Load technique employing a sliding load, and finally the Short-Open-Load employing fixed loads produces the largest residuals.

The values for the residual error terms presented in this paper can be used as a guide to the likely size of residuals found on other calibrated ANAs.

Acknowledgement

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