# 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 is 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

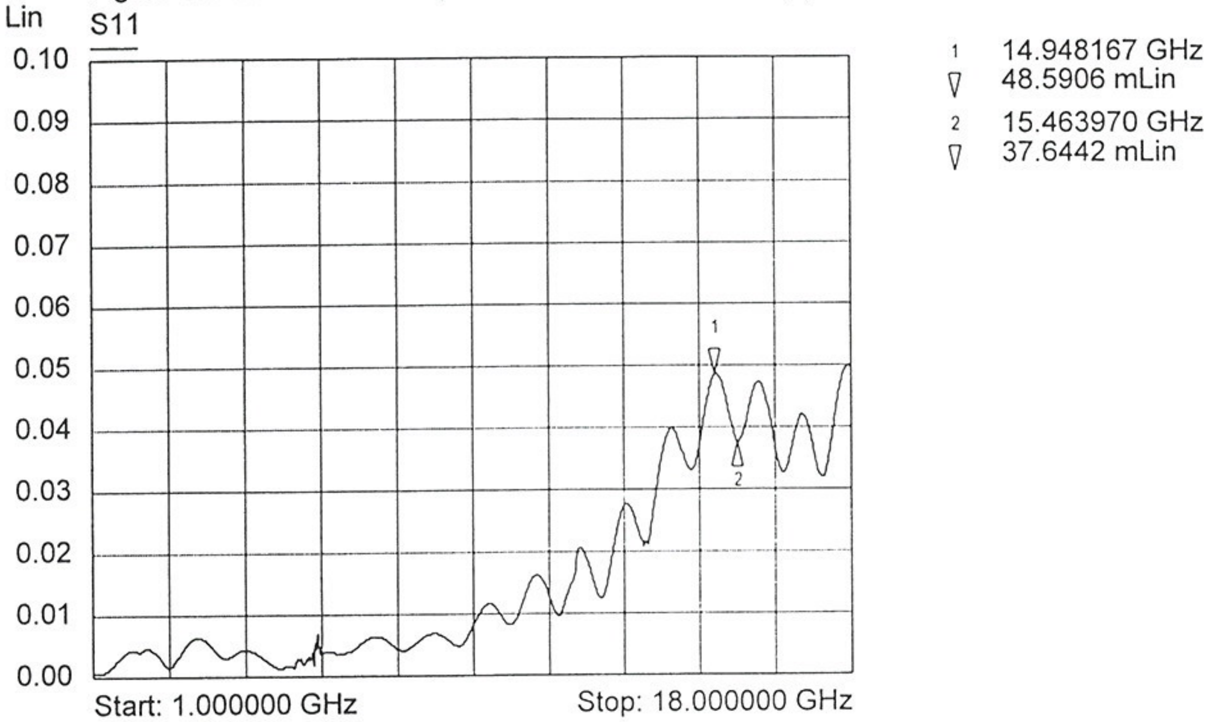


Figure 2: Residual test port match error assessment for the type-N calibration