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into variation in ANA measurements  
due to different calibration loads

N M Ridler & J C Medley

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For further information about ANAMET and its activities contact:

internet: <http://www.npl.co.uk/npl/collaboration/clubs/anamet/index.html>

e-mail: [nmridler@dra.hmg.gb](mailto:nmridler@dra.hmg.gb)

Comments on this report should be sent to:

mail: ANAMET  
PO Box 92  
Malvern  
United Kingdom  
WR14 3YS

fax: 01684 89 5547 (UK)  
+44 1684 89 5547 (elsewhere)

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## ANAMET-971: "LIVE" INVESTIGATION INTO VARIATION IN ANA MEASUREMENTS DUE TO DIFFERENT CALIBRATION LOADS

N M Ridler<sup>1</sup> and J C Medley<sup>2</sup>

### Abstract

*This report presents results obtained from an investigation into the variation in measurements due to calibrating an ANA with a succession of different calibration loads. The investigation was undertaken during the eighth ANAMET meeting, at NPL, Teddington, on the 9th April 1997. The results are compared with those of related investigations to help quantify some of the contributions to the overall variability for the measurements.*

### Introduction

ANAMET measurement comparison exercises are designed to increase the confidence of participants in their ability to make measurements. They also provide useful data on the variation in measured values that can be expected for the measurements being compared [1,2]. In particular, values have been calculated for the measurement repeatability (variation in the results of successive measurements of the same item under the same conditions - same laboratory, ANA, operator, calibration) and the measurement reproducibility (variation in the results of measurements of the same item under changed conditions - different laboratories, ANAs, operators, calibrations).

In comparison ANAMET-951 (voltage reflection coefficient of 50  $\Omega$  Type-N mismatches), repeatability values were found to be around an order of magnitude smaller than the reproducibility values. In [1], the authors suggested that this difference was probably due to imperfections in the loads (fixed, near-matched, terminations) used by the 11 participants in the calibration of their ANAs.

The current report presents the results of an investigation aimed at testing this suggestion. The investigation was performed "live" during the eighth ANAMET meeting, which was held at NPL, Teddington, on the 9th April 1997. Attendees were asked to bring to the meeting good calibration loads, suitable for calibrating an ANA, for use in the investigation. The investigation was assigned the identifier ANAMET-971, in line with other measurement comparison exercises (and now measurement investigations) coordinated by ANAMET.

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<sup>1</sup> Assessment Services, working under contract to NPL, % DRA Malvern, United Kingdom.

<sup>2</sup> NPL, % DRA Malvern, United Kingdom

The measurement investigation - details

An HP 8753A ANA was used as the measuring instrument, set up as follows:

- With a GPC-7 to Type-N (female) adaptor on port 1
- Frequencies: 100 MHz to 1 GHz in 100 MHz steps
- Averaging factor: 16
- IF Bandwidth: 100 Hz

The measurement investigation consisted of an operator (one of the authors) calibrating the ANA 11 times, using the same short-circuit (S/C), the same open-circuit (O/C), and a different fixed load, for each calibration. Each calibration was followed by the measurement of a single device-under-test (DUT) : the Type-N (male) 1.2 VSWR termination used previously as part of the ANAMET-951 measurement comparison exercise. The frequencies used in the investigation are a subset of those used in the ANAMET-951 exercise, however the summary statistics given in [1] are also applicable to the subset of frequencies used here.

The measurement results were stored and displayed on a portable lap-top computer using *SoftPlot Measurement Presentation Software*<sup>3</sup>. By simultaneously displaying the VRC magnitudes of all 11 results, a visual inspection of variability as a function of frequency could be made. Off-line processing of the results allowed a summary figure for the variability to be calculated.

The calibration loads

The 11 calibration loads were of the following types:

- |                        |                     |                  |
|------------------------|---------------------|------------------|
| <i>Hewlett Packard</i> | (i) 85054-60033     | (ii) 85054-60033 |
|                        | (iii) 909 F Opt 012 | (iv) 00909-60011 |
|                        | (v) 909 C           | (vi) 909 F       |
| <i>Wiltron</i>         | (i) 28N50-2         | (ii) 26N50       |
|                        | (iii) 26N50         | (iv) 26N50       |
| <i>Maury</i>           | (i) 2510B6          |                  |

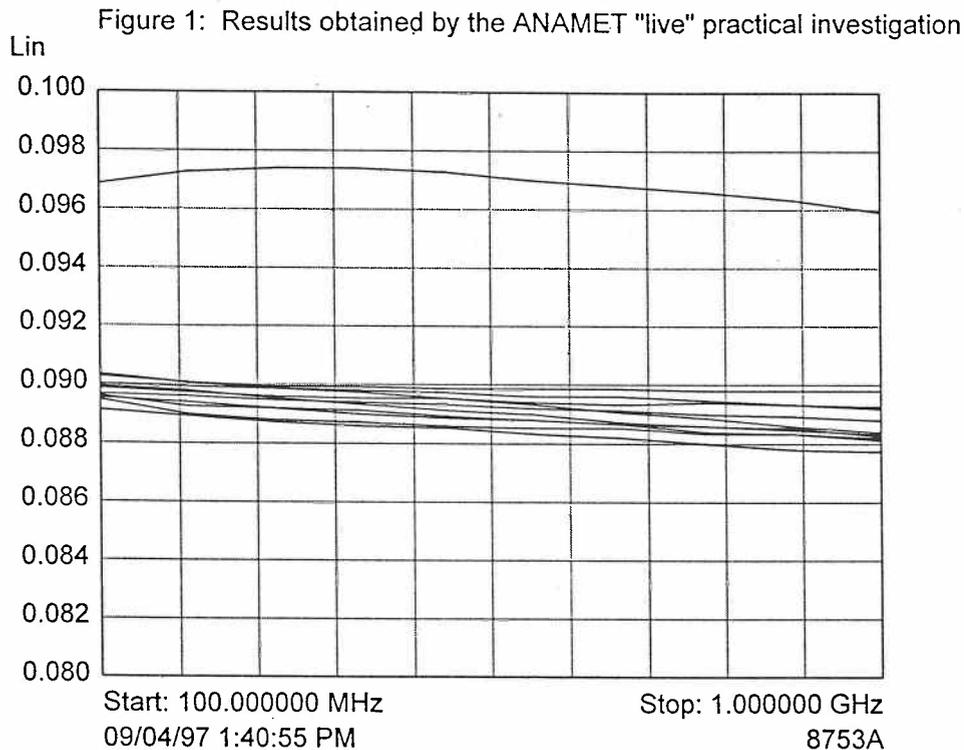
Contributors of calibration loads had been asked to gauge the pin-depth of their loads before the meeting to ensure that the ANA's test port would not be adversely affected by the connection of an unsuitable device.

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<sup>3</sup> *SoftPlot Measurement Presentation Software* is supplied by P & H Technology Consultants, 10 Teversham Road, Fulbourn, Cambridge, CB1 5EB.

## Results

Figure 1 shows a plot (linear magnitude of voltage reflection coefficient (VRC) versus frequency) of the results obtained for the 11 measurements of the DUT.



There is a distinct group consisting of 10 of the 11 traces, while the remaining trace is far-separated from this group. The characteristics of the load used in the calibration of the ANA that produced the far-separated trace were subsequently compared with those of one of the other loads in the comparison. Although the characteristics of the first load were within the manufacturer's specification, they were significantly different from those of the other load.

It seems likely therefore, that this load was not of the same calibre as the other 10 loads used in the ANAMET "live" practical investigation and, in fact, this load was the only one not taken from an ANA calibration kit. This shows that, although a load can meet a manufacturer's specification and give relatively good performance, it may not be of the same quality as a high precision load used for calibrating an ANA.

### Summary statistics

As on previous occasions, the median value [3] of VRC magnitude was calculated at each frequency, together with the median absolute deviation (MAD) [4] of the VRC magnitudes from the median. The MAD remains unaffected by the occasional unusual result in a data set, as occurs in the current data. The same is not true of the sample standard deviation - if it was to be used as the summary statistic for the results, the unusual result would produce an artificially large estimate of the population standard deviation, as indicated by the variability in the other 10 traces.

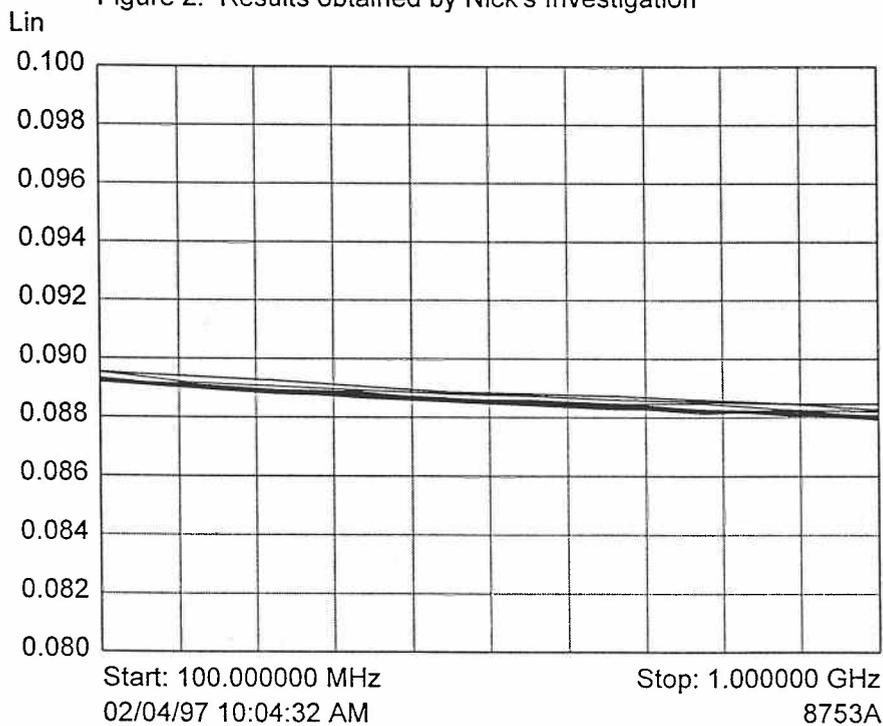
The maximum MAD value ( $MAD_{max}$ ) for the  $|VRC|$  values obtained in the ANAMET-971 "live" investigation was found to be **0.5 mU**.

A supplementary measurement investigation

An additional investigation into the variability of measurements was also carried out by one of the authors prior to the eighth ANAMET meeting. This involved performing successive calibrations followed by a measurement of the same DUT (the 1.2 VSWR termination). However, instead of using different calibration loads for each calibration, the same load was used on each of 11 occasions (thus keeping the same number of measurements in each case). We will call this investigation, "Nick's Investigation".

The results obtained by Nick's Investigation are shown in Figure 2. The  $MAD_{max}$  value was found to be **0.08 mU**.

Figure 2: Results obtained by Nick's Investigation



Comparison with ANAMET-951

The  $MAD_{max}$  obtained for the repeatability and reproducibility of the 11 participants' measurements of the same 1.2 VSWR termination in the ANAMET-951 measurement comparison exercise were **0.07 mU** and **0.7 mU** respectively [1].

## Discussion

The amount of variability, as indicated by the  $MAD_{max}$  values, obtained during the two investigations described in this Report (ANAMET-971 "live" investigation and Nick's investigation) can be compared with that observed in the ANAMET-951 measurement comparison exercise (repeatability and reproducibility). Each of these four situations contains different sources of variation in the measurement process which will affect, to varying degrees, the amount of variation found in the measurement results.

The possible sources of variation are summarised in Table 1, along with a YES/NO marker to indicate their presence/absence in the four measurement scenarios. This Table also gives the summary  $MAD_{max}$  value for each situation. (Electrical noise will contribute to the variability of the results in all four instances.)

Table 1

Sources of variability	ANAMET-951: Repeatability	Nick's Investigation	ANAMET-971 "live" investigation	ANAMET-951: Reproducibility
DUT dis/reconnect	YES	YES	YES	YES
Cal items dis/reconnect	NO	YES	YES	YES
Different cal loads	NO	NO	YES	YES
Different cal S/Cs and O/Cs	NO	NO	NO	YES
Different ANAs	NO	NO	NO	YES
Different operators	NO	NO	NO	YES
$MAD_{max}$  VRC  (mU)	0.07	0.08	0.5	0.7

It is interesting to note how, as more sources of variation are included in the measurement setups (moving left to right across the Table), the  $MAD_{max}$  value increases. For example, including the disconnection and reconnection of the calibration items causes a small increase in the variability ( $MAD_{max}$  increasing from 0.07 mU to 0.08 mU), whereas using different calibration loads causes a substantial increase ( $MAD_{max}$  increasing from 0.08 mU to 0.5 mU).

This would seem to substantiate the suggestion, made by the authors in [1], that the varying amounts of systematic error in different calibration load standards make a substantial contribution to the variability of results in a measurement comparison such as ANAMET-951. In fact one can now go further and suggest that the uncertainties in the calibration load dominate the measurement uncertainty for such systems at these frequencies.

## Conclusions

The ANAMET-971 "live" investigation has examined a (hopefully representative) sample of calibration loads to assess the contribution of load imperfection to measurement quality. The effects due to systematic differences in the loads have been randomised and analysed statistically. The results suggest that such systematic differences are a dominant contribution to the error in subsequent ANA measurements at these frequencies.

## Acknowledgements

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## References

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