ANAMET - Past, Present and Future

N M Ridler
Centre for Electromagnetic and Time Metrology (CETM)
NPL, %DRA Malvern, Worcs, WR14 3PS

Summary

This paper presents a review of ANAMET - the Automatic Network Analyser METrology club, set up in 1993 by the UK's National Physical Laboratory (NPL), for people and organisations interested in RF and microwave network measurements.

The review focuses on the developments and achievements made during the first four years of the club's operation (1993 to date). This is followed by an appraisal of the current status of the club and its activities (e.g., measurement comparisons, research investigations, etc). Finally, potential directions for the future development of the club to the year 2000 (and beyond) are discussed.

INTRODUCTION

It is now four years since NPL set up and launched ANAMET - the network analyser metrology club for people and organisations involved in RF and microwave network measurements. Throughout this four-year period, the club has developed, and grown rapidly, thus making a review of activities both timely and informative.

The decision to launch ANAMET as one of NPL's measurement clubs was made at the beginning of 1993. This followed a period of consultation with industry and other end-users regarding the feasibility and suitability of such an activity. It was clear from the consultation study that ANAMET could provide a useful forum for the exchange of information on topics related to RF and microwave network analysis.

The club was initiated by an inaugural meeting in the late spring of 1993 and became an established activity by late 1993. The club continued to developed rapidly throughout 1994, 1995, 1996 and into the present year. Current signs indicate that the club will continue to grow and evolve as we approach the end of the millennium and indeed into the 21st century.

This paper begins by taking a look back at the beginnings of ANAMET. This is followed by a review of the growth of the club through the mid-1990s leading to an appraisal of its current status. Finally, the potential future directions for ANAMET to the year 2000, and beyond, are investigated. Details of all ANAMET's publications to date are given in the appendices.

1 Mr Ridler is employed by Assessment Services Ltd and works under contract to NPL. He is Technical Advisor on the ANAMET Steering Committee.
THE CLUB'S LAUNCH - ANAMET's activities in 1993

Invitations to attend the inaugural meeting of ANAMET were sent out at the beginning of April 1993 to organisations involved in the earlier consultation study during the formulation phase of ANAMET. The purpose of ANAMET, as described in the literature accompanying the invitation, was "to provide a forum for engineers engaged in RF and microwave measurements on scalar and vector network analysers. This to be achieved by biannual meetings and newsletters, and more importantly by providing a means for the informal intercomparison of validated RF and microwave components."

The inaugural meeting took place in May 1993 and was held at DRA Malvern. Representatives from 17 organisations attended the meeting and, with the ensuing lively debate, set the style for future meetings of the club's membership. The inaugural meeting represented the official launch of the club, and membership was accepted from that date.

In July 1993, the first ANAMET measurement comparison was started. Six type-N mismatches (three male and three female) were circulated to six participants for measurements to be made of VSWR. The comparison was completed, and reports issued to participants, by the end of 1993. A general report on the comparison was given at the 20th ARMMS meeting in March 1994 at the University of Nottingham, and a subsequent article summarising the exercise was published in Microwaves & RF magazine in January 1995. (A list of all publications in the open literature relating to ANAMET is given in Appendix A.)

October saw the publication of the first issue of ANAMET News, the club's newsletter. Also in October, the ANAlyse Technical Note series was launched with the publication of ANAlyse No 1, "Using the memory to extract the ripple on an HP8510C". The ANAlyse series was set up to enable fast dissemination of technical information to the ANAMET community.

The first meeting of ANAMET members took place in November 1993 at the University of Leeds. 12 out of the then 17 member organisations were represented at the meeting. The structure of the meeting was similar to the inaugural meeting but included, in addition, visits of the laboratory facilities at the Electrical and Electronic Engineering Department of the University. Also at the meeting, a Steering Committee for ANAMET was appointed comprising: Ralph Yell, Chairman; Nick Ridler, Technical Advisor; Glyn Jones, Technical Coordinator; Dave Hepworth, Industrial Representative; and, Chris Potter, Instrumentation Representative.

By the end of 1993, ANAMET had made significant progress with its intended activities and the number of organisations who had taken up membership ensured the continuation of the club, at least for the next few years.


The years 1994, 1995 and 1996, saw ANAMET grow and mature into a thriving activity providing substantial benefits for its membership - during the entire period of the club's operation, only one organisation (out of over 40) failed to renew its membership by paying the annual subscription fee of £100.
Membership. The number of organisations joining ANAMET grew steadily over this period (see Figure 1). This has included an increasing proportion of members from outside the UK, thus providing a truly international dimension to the club and its activities. At the time of writing, 69% of the membership is made up of UK-based companies, 21% from mainland Europe and 10% from elsewhere (including the Far-East and Australia). A series of advertisements appearing during this period in Microwave Engineering Europe magazine helped raise the profile of the club at some of the more distant locations.

![Graph](image)

**Figure 1:** Number of member organisations of ANAMET during 1994, 1995 and 1996.

Meetings. The club continued to hold meetings biannually during this period. Meetings were held at a variety of venues, as shown in Table 1, at the invitation of the member host. Attendance at meetings varied between 24 and 32 delegates with 30 being typical for the more recent meetings.

<table>
<thead>
<tr>
<th>Meeting number</th>
<th>Venue</th>
<th>Date</th>
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<tbody>
<tr>
<td>2</td>
<td>Hewlett Packard Customer Support Centre, Winnersh</td>
<td>May 1994</td>
</tr>
<tr>
<td>3</td>
<td>DRA, Malvern</td>
<td>October 1994</td>
</tr>
<tr>
<td>4</td>
<td>EEV Ltd, Chelmsford</td>
<td>April 1995</td>
</tr>
<tr>
<td>5</td>
<td>The Winter Gardens, Malvern</td>
<td>November 1995</td>
</tr>
<tr>
<td>6</td>
<td>SESC, DRA Aquila, Bromley</td>
<td>May 1996</td>
</tr>
<tr>
<td>7</td>
<td>Marconi Instruments Ltd, Stevenage</td>
<td>November 1996</td>
</tr>
</tbody>
</table>

**Table 1:** Details of ANAMET meetings held during 1994, 1995 and 1996.
Measurement comparisons. A further five measurement comparisons have been undertaken and completed since the first exercise in 1993. This makes a total of six exercises completed to date, the details of which are given in Table 2. The last two of these exercises (comparing coaxial connector dial gauge measurements) have been conducted during the last two ANAMET meetings. These "live" comparison exercises (which provide on-the-spot results summaries) have proven to be very popular with the delegates at the meetings, and further such exercises are envisaged for future meetings.

<table>
<thead>
<tr>
<th>Comparison description</th>
<th>Number of participants</th>
</tr>
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<tbody>
<tr>
<td>ANAMET-941: &quot;Complex reflection and transmission coefficients in 3.5mm coaxial line, 1 GHz to 26.5 GHz&quot;</td>
<td>8</td>
</tr>
<tr>
<td>ANAMET-942: &quot;Complex reflection and transmission coefficients in waveguide, 8.2 GHz to 12.4 GHz&quot;</td>
<td>8</td>
</tr>
<tr>
<td>ANAMET-951: &quot;Type-N complex reflection coefficient from 100 kHz to 1 GHz&quot;</td>
<td>11</td>
</tr>
<tr>
<td>ANAMET-962: &quot;Dial gauge comparison of type-N items&quot;</td>
<td>8</td>
</tr>
<tr>
<td>ANAMET-963: &quot;Dial gauge comparison of 3.5 mm items&quot;</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 2: Details of comparison exercises undertaken by ANAMET during the years 1994, 1995 and 1996

An interesting aspect to the comparison exercises is the high proportion of participants from national standards laboratories and NAMAS accredited laboratories. For example, of the eleven participants in the ANAMET-951 exercise (type-N complex reflection coefficient from 100 kHz to 1 GHz), six were national standards laboratories and four were NAMAS accredited laboratories. This illustrates the high standard of measurement in these exercises and this has been recognised by NAMAS (i.e., UKAS) who recently issued the following statement:

"Participation in an ANAMET intercomparison exercise will be considered by UKAS as contributory evidence that a NAMAS accredited laboratory is effectively reviewing the validity of their calibration and test results. Participation in these exercises is therefore encouraged."

Such a statement impacts directly on requirements given in the NAMAS accreditation standard M10 (or, similarly, the European EN45001 standard and the global ISO/IEC Guide 25) requiring laboratories to ensure the quality of their results by implementing checks, including participation in inter-laboratory comparisons.

Results from comparison exercises are reported directly to the participating laboratories in the form of a confidential report which shows the results obtained by the participant with respect to the other participants' values and a statistical summary. This method ensures that each participant can judge their measurements with respect to other participants' values without the identity of the other participants' results being disclosed. General observations concerning
comparison exercises are often published as magazine articles, conference papers (including ARMMS), etc (see Appendix A).

The types of statistical summary accompanying the results reported for the comparison exercises have been chosen to reflect the nature of the measurements in the exercise. In particular, consideration has been given to the vector (i.e., two-dimensional) nature of the measurements (e.g., complex reflection and transmission coefficients) and the tendency for some of the participants' values to be far-removed from the majority of values (i.e., statistical outliers). This has led to the use of multivariate techniques, to allow for the vector nature of the measurements, which are "robust" to statistical outliers. The resulting robust multivariate methods were presented at CPEM 1996 (Conference on Precision Electromagnetic Measurements)².

Publications.

ANAMET established and maintained momentum with its publication series - ANAMET News and the ANAlyse Notes - throughout 1994, 1995 and 1996. Two issues of ANAMET News were published each year. A brief description of each issue is given in Appendix B, which also shows how this activity has evolved and matured over this period.

Appendix C gives a list of titles of all ANAlyse Notes published by ANAMET and Figure 2 shows the cumulative total of Notes published for this period. Following the issue of the tenth ANAlyse Note, the membership agreed that ANAMET should publish a compilation of these ten Notes as an NPL Report, thereby making them available to the general public (See [4], in Appendix A). In future, each successive set of ten ANAlyse Notes will be published in a similar manner.

![Graph showing cumulative total of ANAlyse Notes for 1994, 1995, and 1996](image)

**Figure 2:** Chart showing the cumulative total of ANAlyse Notes for 1994, 1995, and 1996

The early ANAlyse Notes soon established a standard format for subsequent Notes in the series, with Notes varying in length from two to four sides of A4 and subject matter being generally of

² J C Medley and N M Ridler, "Analysing multidimensional measurement comparison data containing occasional erratic points", *CPEM Digest*, pp 51-52, Braunschweig, Germany, 17-20 June 1996.
a tutorial nature. A significant, and growing, proportion of authors of ANALyse Notes have been by non-NPL staff. This demonstrates the novel nature of ANAMET as a communication mechanism, with a multi-way flow of information between the membership rather than the more conventional one-way flow used for most training courses, seminars, etc.

Having established the format and style for the ANALyse series, it became apparent that the club needed an additional publication series to complement the ANALyse series. This resulted in the launch of a new publication series in 1996 called, the ANAMET Report. The new series would be used to report on activities undertaken, in general, by the club membership, e.g., supplementary measurements made during comparison exercises, research investigations, etc. ANAMET Report 001 was published in July 1996, and reported on the first "live" dial gauge comparison exercise. (Appendix C gives a complete listing of ANAMET Reports published to date.)

THE CLUB AT PRESENT - ANAMET's activities in 1997

The first few months of 1997 have been very productive for ANAMET and its activities. The number of member organisations has now stabilised at 42 - well within the initial target range for club membership. The ANAMET mailing list contains approximately 90 named contacts (since each member organisation can nominate up to three representatives from their organisation to receive ANAMET literature).

So far this year, the following publications have been distributed to the ANAMET community: ANALyse 21 and ANAMET Report 004 (in January); ANALyse 22 and ANAMET Report 005 (in February); ANALyse 23 and ANAMET Report 006 (in March); ANALyse 24 and ANAMET Report 007 (in April). Also in March, the eighth issue of ANAMET News was published.

The eighth meeting of the ANAMET membership will be taking place immediately after this ARMMMS meeting (on the 9th April 1997, at NPL, Teddington). The agenda for the meeting includes several technical presentations (e.g., on TDNA and ANA uncertainties) and a "live" practical investigation into the effects of calibration load errors on subsequent ANA measurements.

Throughout this period, ANAMET's seventh measurement comparison exercise has been continuing. This exercise is comparing the characteristics (all four complex s-parameters) of coaxial-to-waveguide adaptors from 8.2 GHz to 12.4 GHz. The items are currently being measured by the national standards laboratory of the Czech Republic prior to despatch to CSIRO (the Australian national standards laboratory).

Finally, information about ANAMET can now be found on the World Wide Web (or internet). Several levels of pages describing ANAMET and its activities can be accessed via the ANAMET web-site address:


Alternatively, the site can be reached through the NPL home page (via "Getting Together" or the CETM page). To date, the site is proving to be a popular one with over 200 visitors during the first quarter of 1997. This represents a rate of slightly over three per day.
THE CLUB'S FUTURE – ANAMET to the year 2000 (and beyond)

Making predictions about the future of any activity, these days, is a risky business. However, since ANAMET's task is to develop in response to the needs of its membership, ANAMET's future remains secure assuming its membership remains active.

A questionnaire containing a range of suggestions for future activities for ANAMET was circulated at the November 1996 meeting. The most popular topic, which the responders to the questionnaire wanted ANAMET to address, concerned evaluating the uncertainty in ANA (and other) measurements. The issuing of guidance documents, holding one-day seminars and colloquia, etc, were seen as possible ways in which ANAMET could address this subject. Good measurement practise guidance documents were also sought in other areas of RF and microwave metrology. Guidance on ANA calibration standards and troubleshooting of the subsequent ANA calibration were also seen as important issues.

Although at this stage, it is not clear how many of the above (and other) tasks ANAMET will be able to address (this will be very dependent on levels of funding, mechanisms of funding, etc), the questionnaire has enabled priority areas where growth could occur to be identified.

CONCLUSIONS

This paper has presented a review of ANAMET - its beginnings, growth and maturity. A summary of all ANAMET's activities, past and present, has been given, including details of: the club meetings; the measurement comparison exercises; the membership; and, the publications. Finally, some of the potential future directions for the club have been outlined.

ACKNOWLEDGEMENTS

The author would like to thank the following members of the ANAMET Steering Committee, past and present, for their contributions to the setting up and running of ANAMET: Ralph Yell, NPL; Glyn Jones, Consultant; Chris Potter, Marconi Instruments Ltd	extsuperscript{3}; Dave Hepworth, EEV Ltd; Ian Instone, Hewlett Packard Ltd. Thanks are also due to John Medley (Club Secretary and Data Analyst), and to Dave Lette (Club Administrator) for invaluable assistance with the day-to-day running of ANAMET.

ANAMET is part-funded by the National Measurement System Policy Unit of the UK Government's Department of Trade and Industry.

\textsuperscript{3} Dr Potter is currently employed by Symbionics Ltd, Cambridge.
APPENDICES

Appendix A: ANAMET publications in the open literature

This appendix lists papers and articles, published in the open literature, about ANAMET and its activities.


(Past ARMS Conference Digests are available, price £5, from Duncan McIntosh, PO Box 1215, Shirley, West Midlands, B90 4YQ.)

Appendix B: The evolution of ANAMET News

This appendix presents edited highlights of material which has appeared in ANAMET News.

Issue 1 was a modest publication running to four sides of A4. Articles were short and included: a welcome message from Ralph Yell; a list of recent publications; a review of ANAMET's inaugural meeting; and, a meetings diary. These articles went on to become regular features in subsequent issues. The issue also contained some short technical articles.

Issue 2 covered six sides of A4 and contained all the regular features found in the first issue. The short technical articles were more numerous and included: "Phase ambiguities in waveguide measurements"; "The Marconi Instruments Reflection Analyser"; "Mating of sexless connectors"; "Observations on ANA detector linearity"; and, "Comparing complex data".
Issue 3 was more substantial than previous issues, running to eight sides on A4. The usual regular features were complemented by three substantial technical features: "Sub 1 GHz measurements in large coaxial systems"; "Some further observations on the ANAMET type-N measurement comparison exercise"; and, "A phase and amplitude transfer standard". (Another regular feature introduced in this issue was the "Status reports on the ANAMET measurement comparison exercises").

Issue 4 set the standard for size for ANAMET News at 12 sides of A4. The regular features were accompanied by a in-depth technical article on adaptor characterisation techniques. Other articles discussed further observations made during the ANAMET-941 comparison exercise and a free wave reflection measurement comparison of samples of RAM (coordinated by DRA Malvern).

Issue 5 followed the size and format of the previous issue. Technical Features discussed an alternative adaptor characterisation technique used for noise measurements, and, the findings from a calibration certificate questionnaire, which had been circulated to a variety of groups of scientists and engineers. A preview to the 7th British Electromagnetic Measurements Conference was also give along with a new regular feature - "Letters to the Editor".

Issue 6 continued in the now familiar style for ANAMET News. Technical features discussed some of the problems of displaying the data from multiple ANA measurements, and work currently in progress at the Warsaw University of Technology, Poland. Another article summarised the results obtained from two recent international measurement comparison exercises of reflection coefficient - the first in 50 ohm coaxial line and the second in 75 ohm coaxial line.

Issue 7 contained an extended feature (in two parts) discussing methods of analysing repeat measurements. The article showed that problems can occur when data not conforming to the normal distribution assumption is analysed using traditional methods. It showed that these problems can lead to disastrous results even for modest departures from normality. This issue also added an additional regular feature to the newsletter, called "What's new in ANAMET?", containing news and other topical information for the ANAMET community.

Issue 8 maintained the "What's new in ANAMET?" regular feature, along with the other regular features appearing in earlier editions. The re-launch of the ANA Traceability Working Party was announced in this issue, along with reviews of some IEE activities: a special issue Proceedings on EM metrology; and, the forthcoming Microwave Measurements Vacation School.

Appendix C: The ANAlyse Technical Note series

This appendix gives a list of all the ANAlyse Notes published to date.

- ANAlyse 1 Using the memory to extract the ripple on an HP8510C
- ANAlyse 2 Using the memory to extract the ripple on an HP8510C. Part 2 - Why it works
- ANAlyse 3 A study of the electrical compatibility of mechanically mateable coaxial lines
- ANAlyse 4 Definitions of some of the terms in common use with ANAs
<table>
<thead>
<tr>
<th>ANA\text{lyse} 5</th>
<th>Time domain measurements using a reflection analyzer</th>
</tr>
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<tbody>
<tr>
<td>ANA\text{lyse} 6</td>
<td>&quot;A comedy of errors!&quot; or &quot;That's not what I mean by 'mean'&quot;</td>
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<tr>
<td>ANA\text{lyse} 7</td>
<td>Making a good estimate of a measurand</td>
</tr>
<tr>
<td>ANA\text{lyse} 8</td>
<td>Assessing the quality of an estimated value</td>
</tr>
<tr>
<td>ANA\text{lyse} 9</td>
<td>The uncertainty of a single measurement!</td>
</tr>
<tr>
<td>ANA\text{lyse} 10</td>
<td>Services Electrical Standards Centre ANAMET-941 observations</td>
</tr>
<tr>
<td>ANA\text{lyse} 11</td>
<td>The type-N measurement comparison exercise - some additional results using different equipment</td>
</tr>
<tr>
<td>ANA\text{lyse} 12</td>
<td>Characteristic impedance of (X-band) waveguide - what it is?</td>
</tr>
<tr>
<td>ANA\text{lyse} 13</td>
<td>New words for new ideas - a look at some of the terminology recommended for expressing measurement uncertainty</td>
</tr>
<tr>
<td>ANA\text{lyse} 14</td>
<td>How much variation should we expect from coaxial connector dial gauge measurements?</td>
</tr>
<tr>
<td>ANA\text{lyse} 15</td>
<td>Making a good estimate of a vector quantity</td>
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<tr>
<td>ANA\text{lyse} 16</td>
<td>Assessing the quality of an estimated value - Part 2: the median absolute deviation</td>
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<tr>
<td>ANA\text{lyse} 17</td>
<td>&quot;Two into one can go&quot; NPL's expression of uncertainty for scattering coefficient measurements</td>
</tr>
<tr>
<td>ANA\text{lyse} 18</td>
<td>Hidden problems when employing partial differentiation in uncertainty assessments</td>
</tr>
<tr>
<td>ANA\text{lyse} 19</td>
<td>Partial differentiation in uncertainty assessments - Part 2: simplifying the problem</td>
</tr>
<tr>
<td>ANA\text{lyse} 20</td>
<td>The uncertainty in the median</td>
</tr>
<tr>
<td>ANA\text{lyse} 21</td>
<td>Practical alternatives to partial differentiation in uncertainty assessments</td>
</tr>
<tr>
<td>ANA\text{lyse} 22</td>
<td>&quot;Converting uncertainty in real and imaginary components to those for magnitude and phase&quot; NPL's expression of uncertainty for scattering coefficient measurements: Part II</td>
</tr>
<tr>
<td>ANA\text{lyse} 23</td>
<td>Assessment of VNAs: contribution of directivity to the determination of test port match</td>
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</tbody>
</table>
ANALyse 24  Assessment of VNAs: contribution of directivity to the determination of test port match - Part 2: associated uncertainty

Appendix D: The ANAMET Report series

This appendix gives a list of ANAMET Reports, published to date.

Report 001  ANAMET-962 dial gauge comparison exercise
Report 002  Draft EAL procedure for the assessment of vector network analysers (VNAs)
Report 003  ANAMET-951 type-N measurement comparison at lower RF - some additional results using different ANAs
Report 004  The ANAMET data analysis game
Report 005  Comparison of Hewlett Packard and draft EAL methods of assessing network analyser measurement uncertainties
Report 006  ANAMET Measurement Comparisons: 931, 942 and 951
Report 007  Live dial gauge comparison exercise: ANAMET-963