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ANAMET-032: “Live” Dial Gauge Measurement Investigation Using Type-N Connectors

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Abstract

This report presents results obtained from an investigation into the performance of coaxial connector dial gauges. Such gauges are used to measure the position (i.e. recession, or protrusion) of a coaxial connector's inner conductor with respect to the outer conductor reference plane. The investigation took place during the 20th ANAMET meeting, held at Agilent Technologies, South Queensferry, on the 11th and 12th September 2003, and concentrated on devices fitted with Type-N connectors. The gauges used for the investigation were supplied by some (five) of the attendees at the meeting. This report presents a general summary of the outcome of the investigation.

1. Introduction

This report presents results obtained from a measurement investigation that was conducted during a recent ANAMET meeting (held in September 2003). The investigation examined the variability of coaxial connector pin-depth measurements made using dial gauges. Such measurements are made routinely in RF and microwave laboratories in order to determine whether a particular coaxial connector is suitable (mechanically) to be connected to other similar connectors. This type of measurement therefore plays a vital role in establishing whether coaxial devices are suitable to be used in a laboratory (e.g. for measurement purposes, etc). Pin-depth measurements can also give an indication of the likely performance of some devices – e.g. a considerable mechanical recession can introduce a significant mismatch at the connector interface that can introduce unwanted electrical reflections at high frequencies [1].

One of the features of ANAMET meetings has been the organisation of 'live' measurement investigations that have taken place whilst the meeting has been in progress. This has enabled the participants in such exercises to see how their measurements compare with other participants at the meeting. An additional advantage has been that the general performance of certain types of measurement, and measurement apparatus, has been evaluated by a group of skilled metrologists brought together as colleagues at the meeting[1]. Previous investigations have looked at the effects of different calibration loads on ANA measurements [2], the variability of connector torque spanners [3], the performance of ANA test port cables [4], as well as coaxial connector dial gauge measurements [5, 6].

On this occasion, five representatives at the meeting chose to take part in the exercise, which consisted of measuring the connector pin-depths of four items fitted with Type-N 50 ohm connectors. The results produced by the participants in the exercise were analysed and presented during the meeting, and caused considerable discussion amongst the representatives. This report presents a general summary of the results obtained from the

[1] However, it should be noted that these investigations are not performed under laboratory conditions and therefore may produce results that are somewhat less reliable than those that could be obtained in a laboratory.

exercise, along with some of the points that were discussed by the delegates at the meeting. The report does not relate specific results to participants (although each participant has been made aware of the identity of their own results in the exercise). The objective here is therefore generally to gain further insight into this type of measurement.

2. Investigation details

The investigation consisted of measuring the connector pin-depths of the four devices described in Table 1, below. This table also contains detailed information concerning the connectors on each item used for the investigation.

Table 1: Descriptions of the four items used for the investigation

Description	Part No	Serial No	Details
20 dB attenuator	8491B	18318	One male and one female connector. No hexagonal nut on the male coupling mechanism so this connector cannot be tightened using conventional torque spanners. Slotted female inner conductor with six-finger contact.
50 dB attenuator	85055-60004	00161	One male and one female connector. Hexagonal nut on the male coupling mechanism enables this connector to be tightened using a conventional torque spanner. Slotted female inner conductor with six-finger contact.
25 Ω air line	85055-60002	00398	One male and one female connector. Unsupported inner conductor – therefore, both connectors are ‘gauged’ simultaneously. Hexagonal nut on the male coupling mechanism enables the male connector to be tightened using a conventional torque spanner. Slotless female inner conductor contact. Male inner conductor pin contained a ‘bullet’ mechanism to facilitate mating.
Type-N to GR900 adaptor	900-QNJ	Labelled IM-1046	One female Type-N connector. Slotted female inner conductor with four-finger contact.

3. Results

The results from the investigation are shown in Table 2 with statistical summaries involving the median [7] to provide an average value and the Median Absolute Deviation (MAD) [8] to provide a measure of the scatter in the data[2]. All values in this table are presented in inches[3] and have been rounded to four decimal places. This corresponds to the units and resolution found on most currently available gauges. Where a participant chose not to supply a result for a particular measurement, the letters NMS (no measurement supplied) have been inserted in the table. Similarly, the letters NA (not applicable) have been used to indicate where a particular value is inappropriate (i.e. the MAD for a sample containing just one value).

Table 2: Participants' results and summary statistics for each connector used for the investigation

Participant number	20 dB attenuator (male)	20 dB attenuator (female)	50 dB attenuator (male)	50 dB attenuator (female)	Air line (male/female)	Adaptor (female)
1	-0.0014"	-0.0002"	-0.0012"	-0.0006"	-0.0003"	+0.0190"
2	-0.0005"	-0.0029"	-0.0012"	-0.0008"	NMS	-0.0024"
3	-0.0014"	-0.0019"	-0.0014"	-0.0006"	NMS	-0.0021"
4	+0.0019"	-0.0020"	+0.0021"	-0.0005"	NMS	-0.0025"
5	-0.0017"	NMS	-0.0012"	NMS	NMS	NMS
Summary statistics						
Median	-0.0014"	-0.0020"	-0.0012"	-0.0006"	-0.0003"	-0.0023"
MAD	0.0003"	0.0005"	0.0000"	0.0001"	NA	0.0002"

4. Observations

The main distinguishing feature between this investigation and earlier ANAMET dial gauge comparison exercises [5, 9] is the wide range of different styles of connector that have been used. In particular, this investigation has included:

- Two different types of male connector: the 'newer' variety which has a hexagonal nut to enable the connector's outer coupling mechanism to be tightened using a conventional torque spanner; and, the 'older' type containing only a knurled nut.

- Different types of female connector, based on whether the inner conductor used a slotted or slotless contact. Two types of slotted contact were included: i) using six slots (producing a six-finger contact); and, ii) using four slots (producing a four-finger contact).

- Connectors (both male and female) featuring unsupported inner conductors (i.e. used to produce unsupported air lines). These connectors are often called Laboratory Precision Connectors (LPC) to distinguish them from the more readily available

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[2] The interval ±MAD is symmetric about the median and contains half the total number of values in a given sample.

[3] One inch (1") is defined as 25.4 mm.

General Precision Connector (GPC)[4]. It is worth noting that LPCs are usually the preferred variety of connector for realising primary national standards of impedance at microwave frequencies.

- A version of male connector containing a retractable ‘bullet’ mechanism in the inner conductor pin. This mechanism is designed to help connect the (unsupported) male LPC to other (supported) female GPCs.

[4] For a more detailed discussion on the different types of connectors and air lines, see [10].

Considering the above points, and the results obtained from this exercise, the following observations can be made:

1) The overall level of variability on this occasion (as indicated by the individual MAD values ranging from 0.0000" to 0.0005")[5] is similar to that observed during previous ANAMET comparison exercises involving pin-depth measurements of Type-N connectors (i.e. see [5, 9], where ranges of MAD values were: 0.00005" to 0.0002"; and, 0.00026" to 0.0004", respectively). This suggests that this level of variability is typical for measurements of this type.

2) On this occasion, it appears that the results for the Type-N male connector capable of being tightened using a torque spanner (i.e. the 50 dB attenuator) show better repeatability (i.e. a lower MAD value) than the results for the Type-N male connector not capable of being tightened using a torque spanner (i.e. the 20 dB attenuator). Although this difference is slight, it does suggest that it is advantageous to use torque spanners to make connections during pin-depth measurements, where possible.

3) One participant (#4) measured the pin-depths of both male connectors to be positive values (i.e. indicating protrusion rather than recession). It was later suggested by this participant at the meeting, during the discussion session that followed the investigation, that there may have been some confusion in reading the gauge, since this participant used a 'dual-purpose' gauge capable of measuring both male and female connectors. (An alternative explanation accounting for these positive readings is given in Appendix A of this report.)

4) Only one participant (#1) provided a measurement for the unsupported air line. Gauging the connectors on unsupported devices with LPCs is considerably more involved (and more difficult) than gauging supported devices with GPCs. This suggests that, on this occasion (i.e. during a 'public' meeting), the participants were reluctant to attempt this more intricate measurement[6].

5) One participant (#5) chose not to provide measurements for the female connectors in the exercise. This participant observed erratic variations in the gauge indication with every movement of the (male) gauge connector onto the female connectors of the test items. There can be difficulties in measuring certain types of female connector, using certain types of gauge, which may have caused this participant to choose to discard these measurements. These difficulties are discussed in more detail in the remaining paragraphs of this section.

6) One participant (#1) measured an extremely large protrusion for the adaptor. This could be due to a combination of the type of gauge used and the diameter of the

[5] It should be noted that a MAD value of zero does not imply that there was no variability in the readings. Rather, it is symptomatic of a significant proportion (more than 50%) of readings having the same value. This can happen when dealing with small samples of measurements recorded with limited resolution. Under these circumstances, estimators like the MAD 'implode' and thus become of limited use for establishing further intervals (such as uncertainty, or standardised, intervals).

[6] This could have been due to a lack of prior notification that unsupported devices were to be included in the investigation. There are extra tools available, in some VNA calibration kits, to facilitate making these measurements which participants may have wanted to use but did not bring with them to the investigation.

hole found in this female connector's slotted inner conductor. On this occasion, the gauge was the screw-on type often found in ANA calibration kits. These gauges connect to the connector being gauged in the same way as a conventional connector and therefore come in both male and female varieties. In this way, they are intended to emulate the performance of a mated pair of connectors, except with the inner 'pin' on the male gauge retracting during assembly enabling the actual position of the connector's inner conductor to be determined.

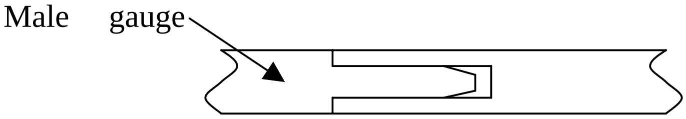
However, if the diameter of the hole in the female inner conductor is too small (e.g. due to tightly sprung contact fingers, produced by the slots) then the pin on the male gauge can become 'trapped' before fully locating in the hole in the female inner conductor. This will result in a reading showing an apparent substantial protrusion beyond the actual position of the female connector's inner conductor[7].

This situation is shown in the following sketches, where: a) shows a male gauge pin on the left and a female connector slotted inner conductor on the right; b) shows the male gauge pin correctly located inside the slotted female connector inner conductor to give a 'correct' reading; and c) shows the male gauge pin 'trapped' by the female connector inner conductor slots producing an 'incorrect' reading. This indicates that these screw-on gauges can produce spurious readings when gauging certain types of slotted female connectors.

a

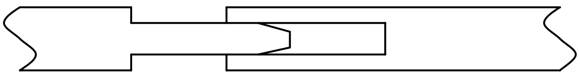
Male gauge pin Female connector inner conductor –

b



Male gauge pin correctly located inside female connector inner

c



Male gauge pin 'trapped' by female connector inner conductor

[7] One method of investigating whether this 'trapping' effect has occurred is to loosen the device, waggle it slightly, then re-connect and re-measure the device. If this produces a significantly different reading (usually a reduction in the amount of measured protrusion), then this suggests that the inner conductor male pin has become trapped before it was able to make a satisfactory connection. Such readings should be treated with suspicion and considered to be unreliable determinations of the connector's actual pin-depth value. (Note that, on some occasions, further 'waggling' of the connector may alleviate the problem!)

5. Conclusions and recommendations

It is clear that this measurement investigation has produced some fascinating results. To begin with, it would appear that none of the participants were entirely satisfied with their involvement with all the measurements on offer. This is evidenced by: only one participant choosing to measure the air line; one participant choosing not to measure the female devices; and two participants obtaining values showing substantial inner conductor protrusions (for either male or female devices).

This indicates that more awareness (possibly, through training exercises) could be useful in improving the quality of these types of measurements. In particular, with: measuring unsupported devices (i.e. LPCs found on air lines in ANA calibration and verification kits); measuring the various types of female connector (including slotted and slotless); and interpreting gauge readings (including considering the effects of the gauge blocks used to calibrate the dial gauges).

Finally, it has become clear that it is, at minimum, useful to get gauge blocks calibrated to ensure their value is known and assured. It is also hoped that further such comparison exercises can take place during future ANAMET meetings and other such gatherings of experienced metrologists.

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7. References

[1] I Instone, "The effects of port recession on ANA accuracy", *ANAMET News*, Issue 11, pp 4-6, Autumn 1998.

[2] N M Ridler and J C Medley, "ANAMET-971: "live" investigation into variation in ANA measurements due to different calibration loads", *ANAMET Report 008*, July 1997.

[3] G J French, “ANAMET-982: Live torque comparison exercise”, *ANAMET Report 022*, February 1999.

[4] A G Morgan and N M Ridler, “ANAMET-031: “live” investigation into the performance of ANA test port cables” *ANAMET Report 040*, October 2003.

[5] N M Ridler and J C Medley, “ANAMET-962: dial gauge comparison exercise”, *ANAMET Report 001*, July 1996.

[6] N M Ridler and J C Medley, “Live dial gauge comparison exercise: ANAMET-963”, *ANAMET Report 007*, May 1997.

[7] N M Ridler, “Making a good estimate of a measurand”, *ANAMET ANAlyse Note 7*, January 1995.

[8] N M Ridler and J C Medley, “Assessing the quality of an estimated value – Part 2: the Median Absolute Deviation”, *ANAMET ANAlyse Note 16*, April 1996.

[9] N M Ridler, M J Salter and S H Fletcher, “ANAMET-021: comparison of Type-N coaxial power splitter measurements from 1 GHz to 18 GHz”, *ANAMET Report 039*, September 2003.

[10] N M Ridler, “Connectors, air lines and RF impedance”, IEE Microwave Measurements training course notes, e-peopleserve Training Centre, Milton Keynes, 13-17 May 2002. (Copies of these notes are available from the author.)

Appendix A: Alternative explanation accounting for the measured protrusions on the male connectors in this exercise

The reference plane for all precision coaxial connectors is defined by the position of the outer conductors. However, for the Type-N connector (unlike other precision pin and socket connectors), the position of the inner conductor is offset from this reference plane. These days, it is generally recognised that this offset is specified to be 0.207" for 'precision' Type-N connectors [A1]. However, there are several other specifications of Type-N connector that give different values for this offset (as discussed in [A2]).

This situation has led to some test equipment manufacturers producing calibration gauge blocks for Type-N connector gauges that have different values for this offset. One such value is 0.210" for so-called 'general purpose' male connectors [A3] (rather than the 0.207" required for setting up gauges to measure with respect to the 'precision' connector specification). Therefore, readings from gauges calibrated using the 0.210" blocks will be offset by 0.003" from readings made using the same gauges calibrated using the 0.207" blocks.

It is interesting to note that the difference between the readings made by participant #4 and the average (median) values for both male connectors in this exercise is +0.0033" (or, approximately 0.003"). It is therefore possible that participant #4 could have calibrated their gauge for measurements of the male connectors with respect to a calibration gauge block of 0.210". Therefore, on the one hand, participant #4 would have been correct in reporting a protrusion with respect to the offset length of their calibration gauge block. However, on the other hand, a conclusion that both male connectors contained protruding inner conductors, capable of potentially damaging other connectors during mating, would be incorrect.

It is therefore important to know against which specification a Type-N connector is being gauged and what is the actual length of the gauge block used to calibrate the dial gauge. This strongly suggests that the calibration gauge blocks, used to calibrate dial gauges, should be calibrated themselves (with traceability to standards of length).

Finally, and in the light of the above potential confusion, the laboratory practitioner should always be in no doubt as to whether any damage may occur whilst connecting various components together. This degree of certainty can only really be achieved when there is full awareness of all the above issues.

References

[A1] IEEE P287/D1, "Draft standard for precision coaxial connectors (DC to 110 GHz", *IEEE Instrumentation and Measurement Society*, August 2001. (This is, at present, an unpublished draft document and therefore not easily obtainable!)

[A2] A D Skinner, "ANAMET connector guide" *ANAMET Report 032*, January 2001.

[A3] "General specifications for coaxial radio frequency connectors", *USA Standards Inst.*, Rep. MIL-C-39012 Class 2.