CALIBRATION TECHNIQUE USING NEW CALCULABLE STANDARD FOR RF REFLECTOMETERS FITTED WITH GPC-7 CONNECTORS

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Abstract

This paper presents new developments made at NPL towards improving traceability for reflection coefficient measurements at RF in 7 mm coaxial line. The developments involve the introduction of a new calculable standard which interfaces with a GPC-7 precision coaxial connector. Results are given illustrating the performance of the new capability.

Introduction

The 7 mm coaxial line size is arguably the most commonly used for high precision impedance measurements at radio frequencies (RF). Its popularity has prompted NPL to research and develop means for impedance traceability at RF in this line size. This paper reports on the progress made towards improving this traceability over the VHF and UHF bands (30 MHz to 3000 MHz).

The traceability route relies on the introduction of a new calibration routine which is a development of an earlier technique implemented in 14 mm coaxial line [1]. This new technique, like its predecessor, relies on a calculable offset open-circuit (O/C) as one of the impedance standards [2]. A recent paper [3] illustrated the application of O/Cs interfaced with a specialised, non-standard 7 mm test port. The current paper gives fabrication details for O/Cs to be used with a conventional GPC-7 connector as the measurement test port, thus eliminating the need for any specialised test fixtures. Results (reflection coefficient measurements for a near-matched load) are presented illustrating the size of the measurement uncertainties obtained using this technique.

Calibration principle

Calibrating a reflectometer requires the determination

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Offset open-circuits

An earlier calibration technique developed in 14 mm coaxial line [1] made use of a novel impedance standard, the calculable offset O/C, to obtain superior performance at RF [4]. The properties of offset O/Cs, like those of offset S/Cs, can be calculated from first principles but they have the advantage of not suffering from the problems experienced with S/Cs at the lower end of the RF band. An offset O/C can be thought of as a finite length of air-dielectric coaxial line (the offset) whose inner conductor is truncated leaving the outer to extend forming an effectively infinite length of circular air-filled waveguide operating below cut-off (the O/C).

Fabrication

Offset O/Cs can be realised for use with the GPC-7 connector test port by removing the short section of inner conductor, which screws into the conductor beyond the connector's support bead, and replacing it with a suitably machined and threaded length of precision inner conductor of the correct diameter. The other end of the conductor provides the abrupt
truncation of the O/C. A length of precision outer conductor (e.g. the outer of a reference air line) is then connected to the test port, extending sufficiently beyond the inner conductor truncation. Different lengths of offset O/C can be used according to the required phase change for the standard, thus providing broadband calibration capability. Care must be taken however, when choosing different lengths, to allow for the length of the section between the connector’s support bead and the connector reference plane.

Modelling

The characteristics of the offset O/C are calculated using a model based on a length of coaxial line terminated with an O/C. The line is modelled using distributed line elements, the values of which depend on the physical properties of the line [5], and the O/C is modelled as a frequency dependent terminating capacitance [6].

Typical results

Typical results for a near-matched load, obtained using this technique, are given in Table 1 in terms of voltage reflection coefficient. The results were produced using a commercially available network analyser as a one-port measuring instrument. The network analyser was calibrated using a zero offset S/C, a 100 mm long offset S/C, and a 7 mm long offset O/C. The measurement uncertainties are specified at a confidence level of not less than 95%.

<table>
<thead>
<tr>
<th>Freq (MHz)</th>
<th>Magnitude</th>
<th>Phase (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Uncert</td>
</tr>
<tr>
<td>200</td>
<td>0.0007</td>
<td>±0.0012</td>
</tr>
<tr>
<td>300</td>
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<td>0.0012</td>
<td>±0.0012</td>
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<tr>
<td>600</td>
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<td>±0.0013</td>
</tr>
<tr>
<td>700</td>
<td>0.0024</td>
<td>±0.0016</td>
</tr>
</tbody>
</table>

Table 1: Results in terms of voltage reflection coefficient for a near-matched load.

Table 1 suggests that a typical magnitude uncertainty for this technique is about ±0.0016 for this frequency range. However, an earlier investigation [7] has shown that uncertainties vary considerably with both frequency and the reflection coefficient of the test artefact. This should be considered when measuring artefacts other than near-matched loads.

Summary

This paper has presented results obtained following a recent development made by NPL for impedance measurement in 7 mm coaxial line at RF. The results indicate a typical discrimination capability of ±0.0016 in reflection coefficient (or 56 dB in return loss) for a perfect match.

References