Calculating measurement uncertainty of conformance test systems for mobile phones

Conformance tests on mobile phones call for utmost RF accuracy. ETSI test specification ETR028 [1], for example, deals with the subject of “uncertainties in the measurement of mobile-radio equipment”. In conformance test systems a reasonable compromise has to be found between measurement uncertainty, costs, automation and test time. This article shows, by way of example, how measurement uncertainties in conformance test systems from Rohde & Schwarz can be determined.

Measurement tasks

Conformance tests on mobile phones not only comprise protocol and audio tests but, very importantly, also measurement of RF parameters for compliance with specifications. The RF parameters are measured in the frequency band of the particular mobile-radio standard (inband) as well as outside this range between 9 kHz and 12.75 GHz (wideband); the applicable test methods are defined by ETR027 [2]. System-specific test methods are described in the specifications for the individual mobile-radio standards, for example in ETS300607 (GSM 11.10) for GSM900/GSM1800, or in ETS300394 for TETRA.

The measurement uncertainties involved in laboratory test setups and in test systems are essentially attributable to the following factors (see also [3] and [4]):

- frequency response of instruments/cabling,
- linearity error of instrument levels,
- mismatch resulting from interconnection of instruments, cables and EUT.

Computation standards

ETR028 is applicable in Europe for determining measurement uncertainties in conformance testing. The official version dates back to 1994 and comprises about 128 pages. In 1997 a draft follow-up version appeared in two volumes with a total of about 420 pages. The later version appears to have been considerably improved in many aspects, so the examples given below are based on this version although it is not yet officially in force.

Strategies in dealing with measurement uncertainties

Advantages and disadvantages of switching matrix

All instruments in a test system are connected to the EUT via a switching matrix (signal switching and conditioning unit – SSCU). Measurement uncertainties caused by mismatch are greater than in a manual test setup unless special precautions are taken. But the major advantage of this method is that the EUT needs to be connected only once and the various test setups can be created by means of relays. This method does away with manual intervention during the test, saves considerable time and avoids operator errors.

Plus, it is possible to compensate the frequency response of instruments and cabling as well as linearity errors of the instruments in a test system – this method is employed, for example, in the path compensation software of Rohde & Schwarz conformance test systems.

Calibration with power meter

The frequency response and linearity error of the remaining instruments and the test setup can in addition be calibrated using a power meter with measurement uncertainty traceable to national standards. For this purpose the power meter, acting as a reference, is connected via relays to suitable test points in the SSCU. Without this calibration the linearity error and frequency response of the signal generators used is approx. 1.5 dB. Calibration of the complete system reduces measurement uncertainty to below 1 dB (at 95 % confidence level).

Calibration of RF generators

As a rule, a signal with a known, fixed level and variable frequency is applied to the EUT in the test cases. For this, the generators have to be calibrated to the nominal levels required for the test cases in question to significantly reduce the effects of generator linearity and frequency error. To save the operator from having to screw the power sensors to the cable to the EUT prior to each test run, the difference between an internal test point and the end of the EUT cable is first measured as a function of frequency and stored. The resulting trace is independent of level and constant over an extended period of time. It is used to calibrate generators at different levels, which can be performed fully automatically and thus immediately before the actual test, thus avoiding errors caused by generator temperature drift. Neglecting uncertainties due to mismatch, the absolute error of 1.5 dB can be reduced to the repeat accuracy (approx. 0.1 dB) and the measurement inaccuracy of the power meter. Depending on frequency and level, this is only about 0.1 dB in the case of Rohde & Schwarz’s NRVD with its Sensor-Z1.
Calculation of measurement uncertainty

Calculation example 1
All the above measurements involve uncertainties due to mismatch however. In ETR028, calculation of these uncertainties is discussed and demonstrated by many examples. The reflections of all RF components involved are added up according to statistical laws. If a large number of components are used, this leads to unnecessarily great measurement uncertainties.

This is demonstrated by an example based on the computation standard for measurement of an EUT that is connected to a spectrum analyzer (“specan” in the formula) via an SSCU (FIG 1) containing relays (K1 to K7) and a 10 dB attenuator (R1). The calculation of measurement uncertainties resulting from path reflections is shown in TABLE 1, where

- Reflections between two neighbouring components are called 1st-order reflections, reflections between two components with one other component between them are called 2nd-order reflections, etc
- Standard measurement uncertainty due to ith-order reflections (see TABLE 1)
- Reflection coefficient of component e
- Transmission coefficient of component e
- Equipment under test

Order | Reflections between neighbouring components (1st-order reflections) | Result
--- | --- | ---
1 | \[ u_{1,\text{EUT}-C_1} = \frac{r_{\text{EUT}} \cdot r_{C_1}}{\sqrt{2 \cdot 11.5 \, \text{dB}}} \] | 0.39 dB
2 | \[ u_{2, C_1-R_1} = \frac{r_{C_1} \cdot r_{R_1}}{\sqrt{2 \cdot 11.5 \, \text{dB}}} \] | 0.039 dB

... | ... | ...

2nd-order reflections

| Reflections between two components with one other component between them | Result
--- | ---
1 | \[ u_{2, \text{EUT}-R_1} = \frac{r_{\text{EUT}} \cdot r_{R_1} \cdot a_{C_1}^2}{\sqrt{2 \cdot 11.5 \, \text{dB}}} \] | 0.27 dB
2 | \[ u_{2, C_1-C_2} = \frac{r_{C_1} \cdot r_{C_2} \cdot a_{R_1}^2}{\sqrt{2 \cdot 11.5 \, \text{dB}}} \] | 0.00 dB

... | ... | ...

9th-order reflections

| Reflections between multiple components | Result
--- | ---
9 | \[ u_{9, \text{EUT}-\text{specan}} = \frac{r_{\text{EUT}} \cdot r_{\text{specan}} \cdot a_{C_1}^2 \cdot a_{R_1}^2 \cdot a_{C_2}^2}{\sqrt{2 \cdot 11.5 \, \text{dB}}} \] | 0.039 dB

Total standard measurement uncertainty \[ \sqrt{\sum x_i^2} \] | 0.56 dB

The data of the components involved are taken from their data sheets.
**Calculation example 2**

According to [1], the scattering matrix of the SSCU can alternatively be measured by means of a network analyzer, the SSCU being treated as a complex component. In the example below, this yields a transmission coefficient of approx. 13 dB and a reflection coefficient of \( r = 0.04 \). FIG 2 shows the frequency response of the transmission coefficient and of the reflection coefficient at the input end.

Calculation is thus reduced to a few steps (TABLE 2). The total standard measurement uncertainty is only 0.18 dB, which corresponds to an expanded measurement uncertainty of 0.36 dB (confidence level 95%).

**Summary**

Even with this simple example, the results obtained with the two computation models differ by more than 0.7 dB at 95% confidence level. The values obtained for example 1, taking into account all SSCU components involved, are apparently too high. However, by measuring the test setup with a network analyzer and treating the SSCU as a complex component in accordance with [1], the measurement uncertainty stipulated by specifications can still be guaranteed for the same wiring.

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**REFERENCES**


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**CD-ROM**

The endless universe, mobile phones flying through space. These are the visionary images that greet the viewer of the CD-ROM presentation for Universal Radio Communication Tester CMU. After the introduction come the details: a transparent, intuitive user interface invites the viewer to go on a discovery trip of CMU. And there is plenty to explore. Just one click and an animated CMU offers an overview of the characteristics and design of the tester as well as potential applications. This part of the presentation describes operation, available measurements and optional device configurations. The user can rapidly create his very own CMU with all the available options using a convenient tool. Configurations can easily be exported for consultation with colleagues or a Rohde & Schwarz sales engineer for example.

The CD-ROM contains the complete data sheet for those needing more in-depth information on the tester. The opening page contains not only CMU data and features but also general information on Rohde & Schwarz, CMU training courses plus a list of worldwide sales offices with addresses and contacts.

All in all this CD-ROM offers a highly practical approach for getting to know CMU and provides a good initial impression of the enormous performance and versatility of Universal Radio Communication Tester CMU.

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