Thermal power sensors up to 50 GHz and 67 GHz

Rohde&Schwarz is further strengthening its position in microwave T&M by launching the world's first coaxial power sensor up to 67 GHz with a 1.85 mm connector (R&S®NRP-Z57) as well as a coaxial power sensor up to 50 GHz with a 2.4 mm connector (R&S®NRP-Z56).

FIG 1 The R&S®NRP-Z56 and R&S®NRP-Z57 thermal power sensors.

Taking the lead in technology

State-of-the-art thermal power sensors offer numerous advantages over their diode-based counterparts. They feature higher accuracy, tolerate any type of modulation, and easily handle harmonics in the test signal. They are therefore the preferred choice for demanding applications. In the microwave range, these superior characteristics are complemented by significantly better impedance matching, which ensures sufficiently high measurement accuracy even with poorly matched sources (DUTs).

Rohde&Schwarz took a radically new approach (see box on page 16) in designing the new products (FIG 1) by developing thermal power sensors that outperform competitive products in terms of accuracy and ease of handling. Going beyond the capabilities of conventional power sensors, they are full-featured measuring instruments and can thus be operated on any PC, the R&S®NRP power meter and many other instruments from Rohde&Schwarz.

Featuring excellent impedance matching, high measurement accuracy and straightforward handling, the two sensors can be used in a wealth of applications, e.g. as high-precision power references for metrological applications, for power calibration on signal generators, network and spectrum analyzers, and for a wide variety of applications in radiocommunications.

Excellent impedance matching

The accuracy of an instrument can generally be increased by determining its measurement errors during calibration and using the results to correct the measured values. This method fails, however, in the case of effects that cannot be handled through calibration and therefore often have to be left unconsidered. These include stochastic effects such as noise and reproducibility of the RF connector and, most importantly, the measurement uncertainty resulting from mismatch of the power sensor.

Impedance matching of power sensors

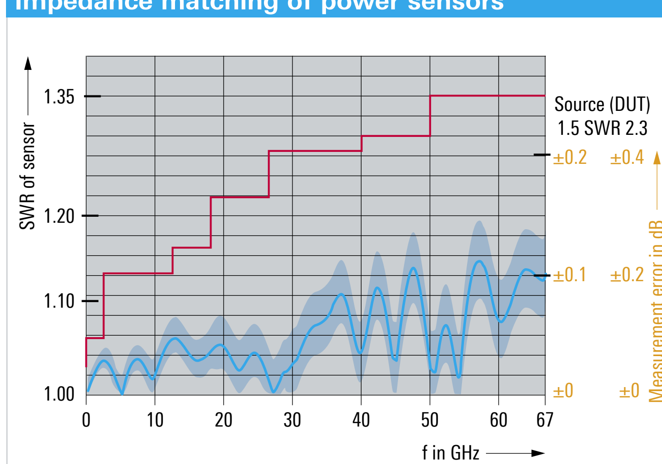


FIG 2 Impedance matching (SWR) of the R&S®NRP-Z56 and R&S®NRP-Z57 thermal power sensors: specified limits (red) and measured data for the R&S®NRP-Z57 (blue) with measurement uncertainty shown in light blue. The labeling in orange on the vertical axis to the right shows the maximum possible measurement error caused by mismatch for two sources (DUTs) with an SWR of 1.5 and an SWR of 2.3.

Minimizing mismatch uncertainty has therefore been one of the primary goals in development. This goal has been reached by implementing the best impedance matching currently achievable with coaxial power sensors for the frequency range in question (FIG 2). While potential mismatch uncertainties cannot be ignored, they are so small that they usually do not impair measurements. For highly demanding applications, it may be necessary to reduce mismatch uncertainties even further. The two new sensors also meet this requirement by means of their gamma correction function.

High stability under all environmental conditions

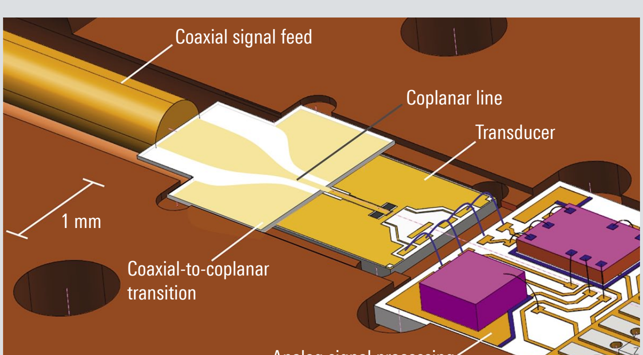
Especially for precision measuring instruments such as thermal power sensors, high reproducibility of results is a vital requirement. This also calls for immunity of the sensor with respect to changes in environmental conditions. The factor that has the most detrimental effect on a thermal sensor is – inherently – temperature. A change in temperature will have two effects: First, as the temperature difference between the sensor and its environment grows, zero drift will occur. This will be followed by a change in the sensitivity of the thermoelectric transducer as the transducer heats up or cools down. While the second effect can be largely eliminated by measuring the sensor temperature and applying suitable correction algorithms, zero drift cannot really be corrected using a mathematical approach.

State-of-the-art technology – patent pending

Thermal power sensors convert the applied power into heat and measure the resulting increase in temperature. Their main elements are, therefore, a broadband, well-matched termination and a temperature-sensing device. State-of-the-art microwave power sensors and their predecessors are worlds apart, however, when it comes to design. This holds true for the physical dimensions of the transducer, which has shrunk to the size of a pinhead as higher and higher frequency ranges have opened up, as well as for the temperature-sensing device. The sensitivity of this device has been continuously improved. Plus, rather than measuring the absolute temperature of the termination, only its increase in temperature is measured using a thermocouple pile, which delivers results that are less dependent on ambient temperature.

If the objective is to extend the frequency range up to 50 GHz or 67 GHz, as in the case of the two new products, and achieve excellent impedance matching at the same time, further miniaturization alone will not produce the desired effect. The problem lies with the mechanical tolerances of lathed or milled parts.

FIG 3 RF frontend (patent pending) of the R&S®NRP-Z56 and R&S®NRP-Z57 thermal power sensors.



With a 1.85 mm connector system, which is required for attaining the 67 GHz frequency limit, a classic design consisting of a large number of individual components would yield a less-than-optimal result. For the two new power sensors this meant reviewing the design of the entire RF signal path.

The result of this effort is a considerably simplified and radically new topology, where the transition from the connector's coaxial line structure to the transducer's coplanar line structure has been implemented by means of photolithography (FIG 3). Due to its small structural tolerances in the order of a micrometer, the transition exhibits highly reproducible performance. At the same time, it provides excellent thermal isolation. This offers the advantage that in the event of temperature differences between the DUT and the thermoelectric transducer, only very small amounts of heat will enter the sensor.

The transducer itself is a Rohde&Schwarz development based on thin-film technology with a measurement range from –35 dBm to +20 dBm. The increase in temperature of the termination is in the order of 10^{-4} K at the lower measurement limit, reflecting the stringent demands placed on heat management. The new power sensors are DC-coupled in the same manner as the predecessor models. As a result, they feature a continuous frequency range from DC to the upper measurement limit, plus they can be linearized with ultra-high accuracy using DC voltages.

For this extremely high linearity to be supported throughout the sensor's signal processing chain, processing of the full power measurement range by the A/D converter without any switchover was required. What is impossible to achieve with classic power meters could be easily implemented by employing the concept of an integrated power meter, i.e. using a low-noise amplifier tailored to the transducer and an integrating 24-bit A/D converter. The resulting linearity of 0.007 dB sets standards.

To minimize zero drift, therefore, an elaborate heat management is needed. The new sensor topology has enabled significant improvements in this area, reflected by a considerably reduced zero drift and a lower measurement limit of –35 dBm, which represents an improvement by a factor of three. This is good news for users, as it means an enhanced reproducibility of results and an infrequent need for zero adjustment even under varying environmental conditions (FIG 4). Due to the minimal zero drift, the zero correction carried out in production will in many cases be entirely sufficient.

Accurate calibration

Whereas with most commercial thermal power sensors only a frequency-dependent calibration factor for absolute measurement accuracy is determined, calibration of the R&S®NRP-Z56/-Z57 also covers linearity, impedance matching and zero offset. In conjunction with hardware offering high long-term stability, this yields ultra-high measurement accuracy, which is reflected, for example, by excellent linearity. A specified value of 0.007 dB across the full power measurement range makes the new sensors an ideal choice for performing high-precision relative measurements.

Calibration of absolute measurement accuracy from DC to 50 GHz is directly traceable to primary standards of Germany's National Metrology Institute (Physikalisch-Technische Bundesanstalt, PTB) [1], and above 50 GHz to the relevant standards of the US National Institute of Standards (NIST). Gamma correction yields specified measurement uncertainties in the order of 0.15 dB (50 GHz) and 0.25 dB (67 GHz) [2].

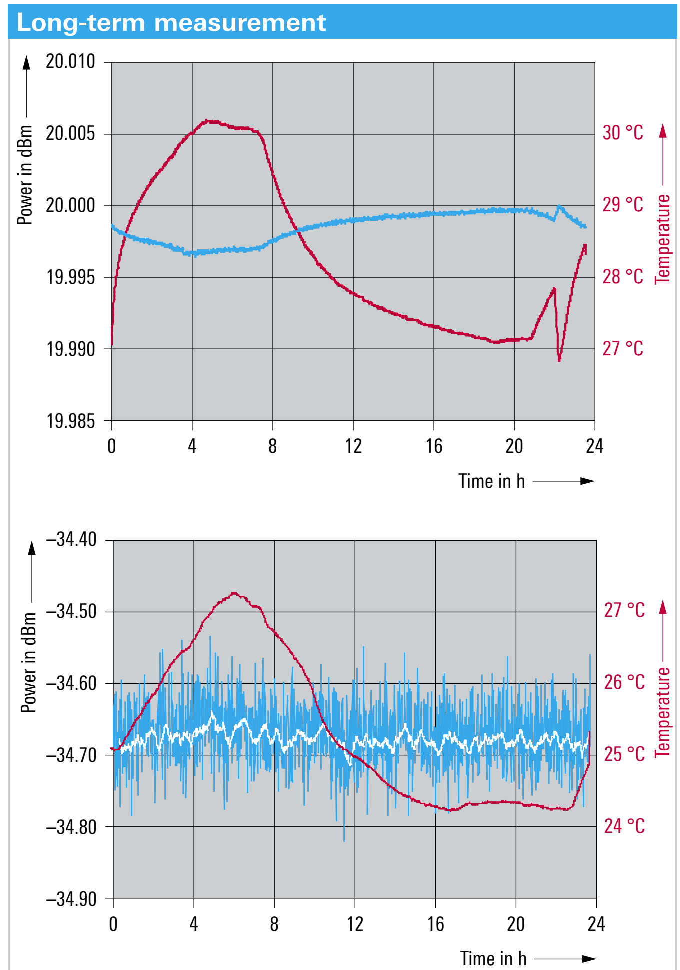


FIG 4 Long-term measurement with an R&S®NRP-Z56 thermal power sensor in a typical work environment. Blue (white): results of power measurement. Red: ambient temperature.

High reliability

Rohde&Schwarz has implemented a special verification function in the R&S®NRP-Z56/-Z57 sensors. This function covers all essential components of the signal path. The thermoelectric transducer therefore contains, in addition to the RF termination, a second heating element which can be fed from an internal, highly stable DC source. Using a test routine, the sensor's response to the applied DC power is measured and compared against the value stored during the previous calibration. With reproducibility in the order of a few thousandths of a dB, highly reliable results will be obtained, providing information about the functionality and accuracy of the power sensor. Two further advantages: The power sensor can remain on-site during verification, and verification can even be performed while another measurement is carried out.

An important component could not be included in the verification loop: the connector and its RF characteristics. Because wear and tear can impair connector performance and result in poor reproducibility and even failure of the power sensor, Rohde&Schwarz has added a truly tangible product innovation: A coupling nut with a ball bearing keeps the connector interfaces from twisting relative to each other during tightening, thus preventing premature wear.

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References
[1] Dr.-Ing. Rolf Judaschke, Physikalisch-Technische Bundesanstalt (National Metrology Institute of Germany): Traceability of RF measurement quantities to national standards. News from Rohde&Schwarz (2009) No. 199, pp. 28–33.
[2] Dr. Gerhard Rösel: RF power calibration at Rohde&Schwarz. News from Rohde&Schwarz (2009) No. 199, pp. 34–37.