Fig. 1 R&S®NRP-Z58 USB power sensor with adapter for the WR-10 waveguide band (R900, WG-27) from 75 GHz to 110 GHz.

Power sensor with 1 mm coaxial connector covers the frequency range from DC to 110 GHz without interruption

Until recently, there was no worthy solution available on the market for power measurements on wideband sources up to 110 GHz, or for level calibration of network analyzers that have 1 mm test ports. The available V-band and W-band power sensors are based on obsolete technology, and they cover only the signal components within their respective frequency band. This means that users need multiple, harmonized sensors to perform broadband measurements. Not so with the new R&S®NRP-Z58 thermal power sensor: It covers the entire frequency range from DC to 110 GHz without interruption.

We recognized a need …

When looking for power sensors that can be used for applications in the millimeter-wave range, the selection on the market is very small. Many of the available sensors use extremely outdated technology. This applies to the frequency range from 67 GHz to 75 GHz and for the W-band (75 GHz to 110 GHz). In fact, only one rather old, diode-based sensor type and one calorimetric-based power sensor are available for the W-band. These sensors cannot be used to detect signals below the cutoff frequency for the type of waveguide used by the sensors, for example. This makes it difficult to perform power measurements on wideband sources such as photodetectors and photoreceivers for the 100G Ethernet. Similar problems exist for level calibration of network analyzers having 1 mm test ports. Previously, the only calibration option was to measure individual frequency ranges sequentially using the appropriate power sensor for that range. In addition, an adapter was needed between a waveguide power sensor and the coaxial connector at the source. Aside from the effort involved and the lack of automation, this method is also associated with greater wear and tear on the sensitive 1 mm connector. This wear and tear is caused not only by the repeated connections that are required when changing the sensor, but also by the mechanical stress resulting from the greater weight and larger dimensions of conventional waveguide power sensors.

Thermoelectric transducer

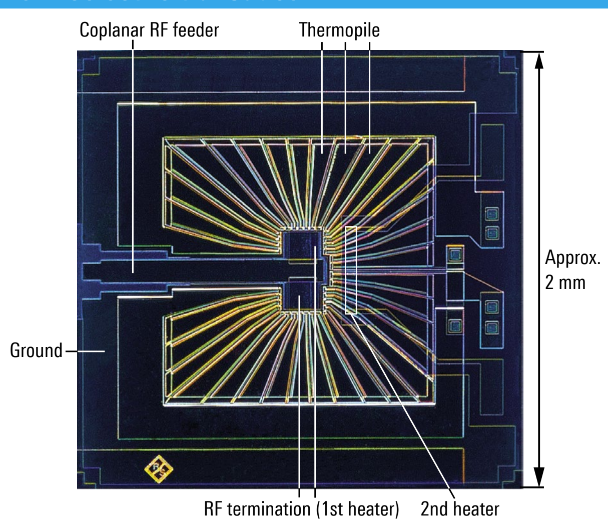

Fig. 2 Structure of the thermoelectric transducer – a Rohde&Schwarz development.

… and brought an innovative product to the marketplace

With the new R&S®NRP-Z58 thermal power sensor (Fig. 1), these problems are a thing of the past. A single 1 mm coaxial connector (male) makes it possible to cover the entire frequency range from DC to 110 GHz without interruption. The power measurement range extends from 0.3 µW (–35 dBm) to 100 mW (+20 dBm), covering the range of greatest interest. The new power sensor is also lightweight and easy to use, and can be operated directly from a PC via a USB interface. Other exceptional features include rapid measurements, excellent linearity, an internal verification option and full traceability to the primary standards from renowned national metrology institutes. Not only is the R&S®NRP-Z58 the first choice for power measurements on 1 mm coaxial ports, it can also replace waveguide power sensors in many other applications (see box on page 25).

The R&S®NRP-Z58 110 GHz power sensor is part of the R&S®NRP family of products from Rohde&Schwarz, and it incorporates all the main features of this family of products. At the core of the new power sensor is the indirectly heated thermoelectric transducer – a Rohde&Schwarz development that combines very good impedance matching values with a high dynamic range and a response time of only a few milliseconds (Fig. 2). The connection to the RF frontend is via a patent-pending wideband transition that converts the radially symmetric field of the incident wave to the field distribution of the coplanar transducer input, while at the same time providing excellent thermal isolation (Fig. 3). These and other thermal design measures ensure that the zero drift remains negligible, even with ambient temperature changes or when screwing on the sensor. Virtually no drift is expected under constant ambient conditions, because the architecture of the signal processing chain ensures that the 1/f noise is suppressed completely. This is why the zeroing performed at the plant is sufficient in many cases. In addition, the R&S®NRP-Z58 does without an internal zeroing function; it would cause long, asynchronous interruptions in the measurement without providing improvements.

Internal DC reference voltage

To verify the thermoelectric transducer and the connected analog signal processing chain, the R&S®NRP-Z58 power sensor has a DC reference (Fig. 4) that makes calibration to an external 50 MHz reference source unnecessary. During calibration, the power sensor can remain connected to the DUT for as long as the DUT supplies a sufficiently stable signal. With a reproducibility in the range of 10^{-4}, verification via the integrated DC reference far exceeds an external calibration with an RF signal.

The factory calibration for more than 200 frequencies is fully traceable to the primary standards of the national metrology institutes in either Germany (Physikalisch-Technische Bundesanstalt, PTB) or the United States (National Institute of Standards and Technology, NIST). In addition, Rohde&Schwarz benefits from a microcalorimeter very recently put into use by the PTB that covers the entire W-band. In this range, the calibration uncertainties of the new power sensor are 6.0 % to 7.0 % (calculated using GUM with a coverage factor of two).

Highly linear power display

A high degree of linearity for the power display was a top priority during development, because this attribute is important for relative measurements. These include scalar attenuation, amplification and reflection measurements, as well as indirect power measurements using directional couplers and so on. The absolute reference for indirect power measurements is normally obtained by means of a system calibration at a single level. With a linearity uncertainty of maximally 0.23 % (0.01 dB), the R&S®NRP-Z58 is comparable to conventional, thermistor-based power sensors that use a DC substitution to ensure high linearity. In the R&S®NRP-Z58, the DC substitution was omitted in favor of measurement speed. Instead, a numeric linearity correction is used. This linearity correction is based on a calibration of the thermoelectric transducer with DC voltages performed at the plant, and it can remain unchanged for the life of the sensor.

Measurement speed

Although the attainable measurement speed is comparable to that of any other state-of-the-art thermoelectric power sensor, it can vary significantly depending on the application. If the only goal is to record as many readings as possible within a given time span, the mode that includes buffering can be used to record more than 500 readings per second. The

R&S®NRP-Z58 frontend

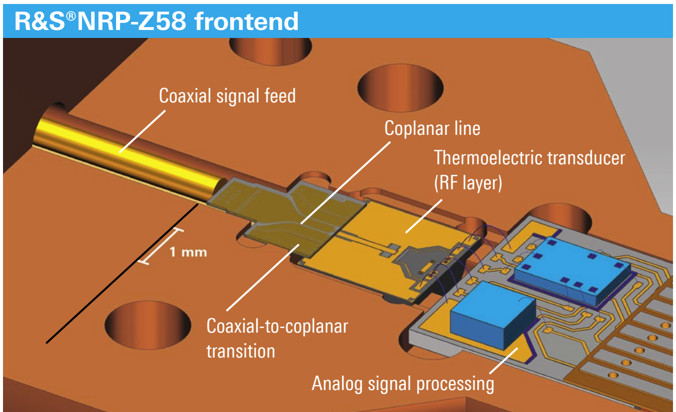

Fig. 3 RF frontend with coaxial-to-coplanar transition.

Calibration with DC reference

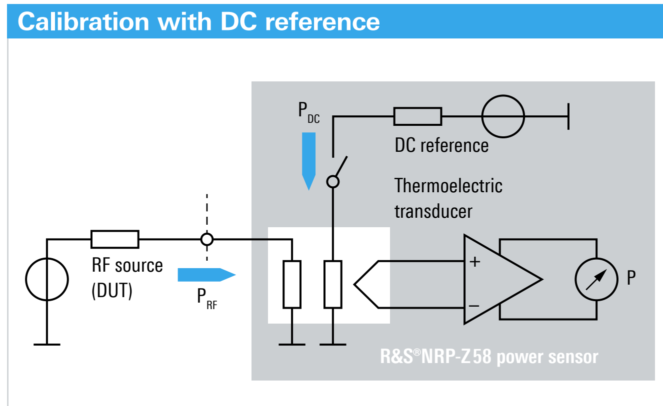

Fig. 4 Circuitry for internal calibration with DC voltage.

Power measurements on any interface in the frequency range up to 110 GHz

Although the R&S®NRP-Z58 power sensor was developed for broadband applications with a 1 mm connector, it can also be used on waveguide interfaces by using a suitable adapter (Fig. 5). This opens up entire new possibilities for these applications. In principle, only one R&S®NRP-Z58 is needed to perform power measurements on any interface in the frequency range up to 110 GHz. This makes it easy to measure in those frequency bands for which a waveguide power sensor is not commercially available, such as the WR-12 band (R740, WG-26) from 60 GHz to 90 GHz. In this case, it is possible, of course, to equip a waveguide power sensor for the WR-10 band with an adapter for WR-12, but this is not a very viable option. The long waveguide sensor would be extended even more, and the already small frequency range would shrink to the overlap with the waveguide band on the DUT, i.e. to the band from 75 GHz to 90 GHz.

In addition to its universal usability, there are other solid arguments for using the R&S®NRP-Z58 in waveguide applications; arguments that more than outweigh the disadvantages associated with adapters. These include significantly faster measurement speed, elimination of the cumbersome alignment to a 50 MHz reference source, higher temperature stability, full traceability of the calibration, the thermal measurement principle and last, but not least, operation without a special base instrument.

Attenuation of the upstream adapter and its interaction with the input of the power sensor can be elegantly compensated by means of embedding. To make this possible, the R&S®NRP-Z58, like all power sensors in the R&S®NRP series, includes S-parameter correction functionality. It allows the four S-parameters of the adapter to be stored in the sensor for many frequencies, and then be automatically included in the measurement result. The effect of the reflection on the waveguide input of the power sensor, which on average is slightly increased by the adapter, can only be compensated by gamma correction. Although this method is also implemented in the R&S®NRP-Z58, the user must know the complex reflection coefficient at the output of the DUT. If this value is known, the remaining mismatch uncertainties are negligible. Otherwise – at least with high accuracy requirements and a poorly matched DUT – the possible effect of the mismatch on the measurement result should be estimated.

Fig. 5 R&S®NRP-Z58 power sensor with adapter for the WR-10 waveguide band (R900, WG-27) from 75 GHz to 110 GHz.

aperture for a measurement point can be set very precisely to a half-millisecond, and the measurement can be either triggered or run continuously. Even if every reading is output separately instead of being buffered, about 350 triggered test results per second are still possible. Of course, the rate of measurement will be slower during low power measurements when it becomes necessary to average multiple test results in order to obtain a stable reading. However, the R&S®NRP-Z58 can use averaging factors that are lower than those required by other W-band products because its inherent noise is significantly lower. As a result, the settling times are more than ten times shorter than before, which means that even levels up to –10 dBm can be measured virtually without delay, while maintaining a satisfactory degree of stability.

Mechanically ruggedized and extremely precise

The 1 mm connector on the R&S®NRP-Z58 is essential for the impedance matching, reproducibility and load capacity of the new product. This is why Rohde&Schwarz manufactures the connector at its own plant, where it is also subjected to a rigorous quality control. The coupling nut on the connector is fitted with ball bearings. These make it possible to hand-tighten the power sensor so precisely that there is no need for a torque wrench. The reduced friction also prevents the outer conductor from rotating when the coupling nut is tightened, thereby reducing wear and tear on the connector.

Thomas Reichel