Innovative Calibration Service for Coaxial Noise Sources

In mobile communication, the radio signal must be well above the noise in order to establish a connection between a mobile phone and a base station. Therefore, it is important to measure noise levels accurately. METAS has become the leading European National Metrology Institute for the calibration of coaxial noise sources at radio and microwave frequencies. Why is this service needed and how does it work?

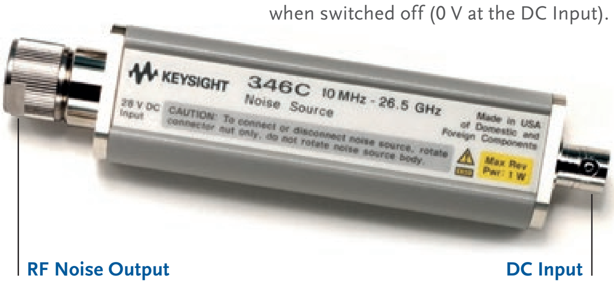
Daniel Stalder

We are all familiar with noise: Acoustic noise from the nearby passing train impeding the conversation with your colleague. Or image noise when taking pictures with your cellphone under low light conditions. The latter is due to electric noise within the image sensor. It becomes visible in situations with little light and the long exposure time associated with it – or in a more general sense, where the ratio between the wanted signal and the undesirable noise is low.
Accurate radio frequency and microwave (RF) noise measurements help to reduce the radiation levels of wireless communication systems: By minimizing the noise in a receiver system, one can reduce the transmitter power accordingly. This leads to lower radiation levels and less energy consumption. Exposure to electromagnetic radiation is a sensitive topic, which is currently much debated with the introduction of 5G networks. In order to characterize the noise properties of a receiver or amplifier accurately, metrological traceable noise measurements are required.

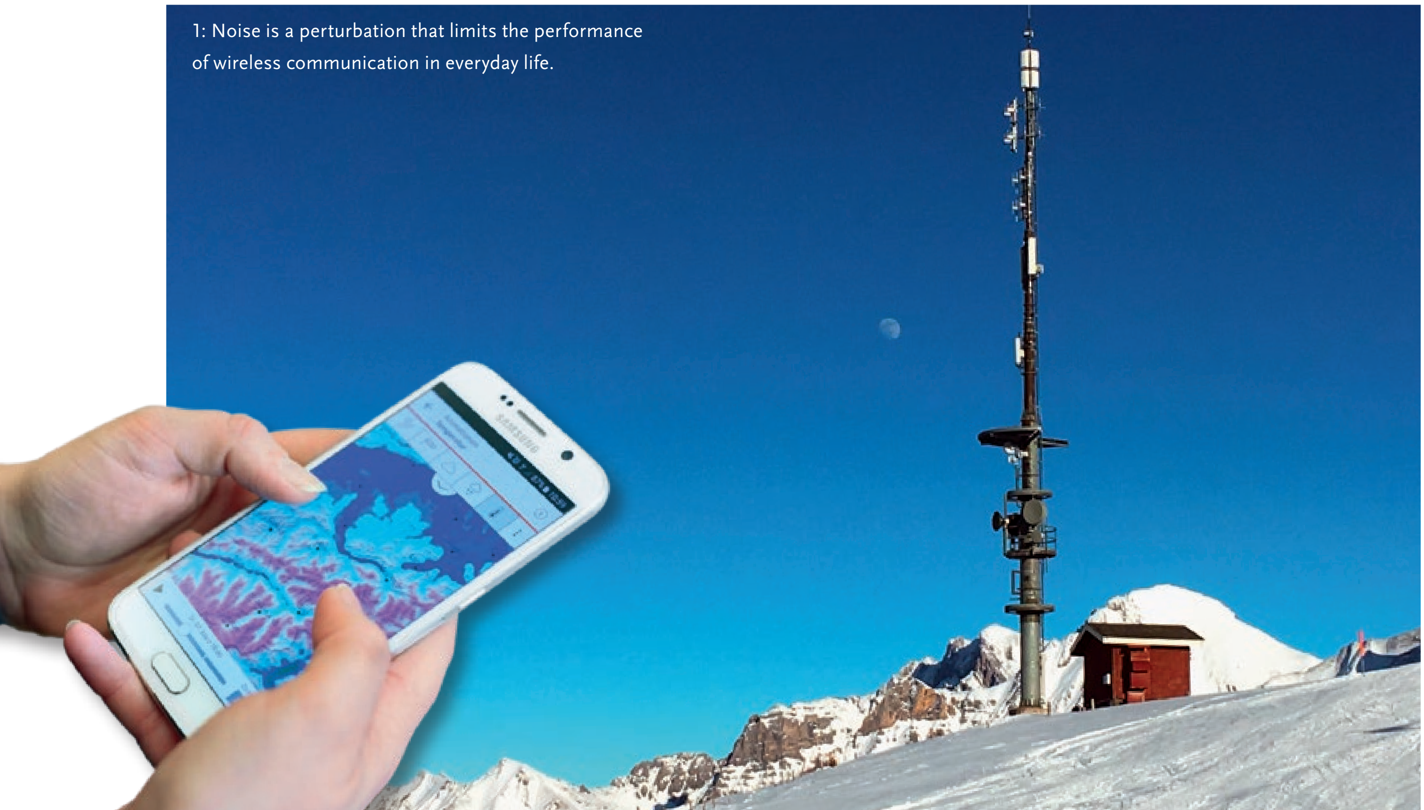
How to Characterize Noise?

The sensitivity of any RF receiver system is limited by the electrical noise present within the system. This noise can be characterized by applying two known noise levels to the input. Coaxial noise sources – see Figure 2 as an example – are able to produce two reference noise levels. They serve as calibration standards in industries and in secondary calibration laboratories.

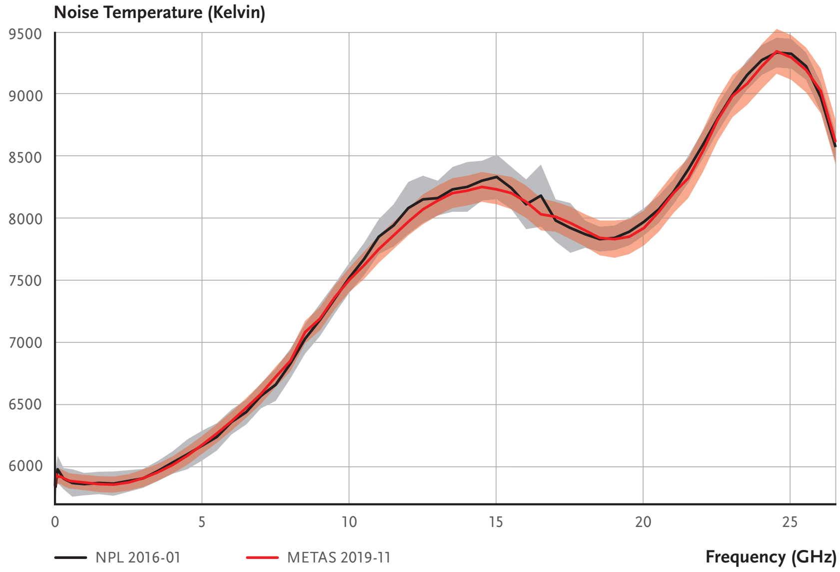
2: Typical Coaxial Noise Source: Generates a high noise level when switched on (+28 V at the DC Input) and a low noise level when switched off (0 V at the DC Input).



METAS now offers a primary calibration service for these noise sources up to 33 GHz. The term «primary» refers to the fact that the reference standard is not calibrated by or subordinate to other standards of the same measurement quantity.



1: Noise is a perturbation that limits the performance of wireless communication in everyday life.



3: Comparison of the results for a coaxial noise source with associated uncertainty areas, which contains the value of the measured quantity with a probability of approximately 95 %. The noise level of a noise source is usually expressed as noise temperature. Noise temperature and noise power density are linearly related.

Becoming a Global Leader in Coaxial Noise Source Calibration

Before 2019, METAS provided a secondary calibration service for coaxial noise sources. The reference standards were coaxial noise sources calibrated at the National Physical Laboratory (NPL) in the UK.

Mid 2018, NPL has closed its primary noise calibration service. There was no other National Metrology Institute (NMI) in Europe (according to the BIPM CMC database) providing a comparable primary calibration service. Comparable accuracy and frequency coverage remained only available at the National Institute of Standards and Technology in the USA.

Therefore, METAS decided to build up its own primary calibration service. Our calibration method is different compared to the traditional method used at other NMIs: Our primary measurement standard for noise temperature is based on RF power and equivalent noise bandwidth. The traditional method uses heated and/or cooled loads, held at a constant known temperature.

Why does METAS not use the traditional method? RF power measurements are already well established at METAS. Therefore, all the necessary equipment was already available to set up a measurement system based on RF power. Realisation was possible with reasonable effort and without any specially dedicated noise standards.

Comparing the Methods and Conclusion

We have compared our measurement results, using the RF power method, with previous calibrations performed by NPL, using the traditional method with heated loads. Figure 3 shows the characterization of a noise source performed by NPL and the results of METAS. The agreement between the curves is very good and the associated uncertainties of METAS are similar to those of NPL.

The new improved service (see box on page 22) has been launched by METAS at the beginning of 2019, leaving only a gap of a few months during which Europe was left without primary noise calibration service. Since then, a larger part of NPLs previous customer base has been taken over by METAS.

Contact:
Daniel Stalder
Laboratory RF and Microwave
daniel.stalder@metas.ch
+41 58 387 07 35

Primary Methods and Measurement System

The Traditional Method

The traditional method is based on thermal noise standards consisting of heated and/or cooled loads (hot/cold standards) held at a known constant temperature. Thermal noise refers to the thermal movement of charge carriers, usually electrons, in a conductor without any applied voltage. The higher the temperature of the conductor, the stronger the movement and therefore the electrical noise. The physical temperature can be converted into noise power density. The challenge of this method is the transition line, which connects the heated/cooled load with the measuring instrument at ambient temperature. The hot-standards used by NPL were operated at around 400 °C.

The RF power Method

The traditional hot standard is replaced by an equivalent hot standard based on RF power and equivalent noise bandwidth (ENBW), see figure 4. The ENBW of a filter is the bandwidth that corresponds to the one of a rectangular filter producing the same integrated noise power. The equivalent noise power density results directly from the calibrated RF power divided by the ENBW.

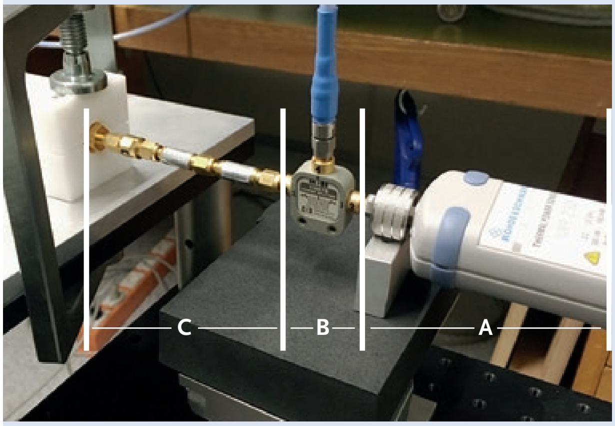
As main advantages of the RF power method, no heated standards are required and the noise power density of the equivalent hot standard is much higher. On the other hand, the system needs to be calibrated in terms of ENBW and the RF power standards are required.

The Measurement System at METAS

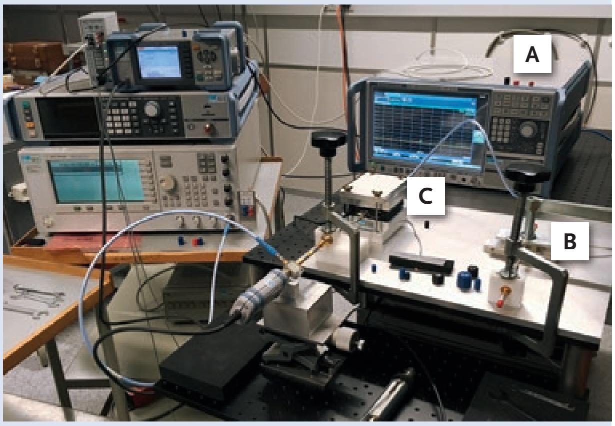
The measurement system shown in figure 5 is used for the comparison of the noise power density of the calibration item (customer noise source) and the calibration standards (equivalent hot standard and ambient temperature standards).

Any measurement system adds noise to the input signal, which needs to be taken into account. In contrast to the basic noise measurement model, which only takes into account the equivalent input noise, we use a complete model. This has the following three additional noise parameters: emerging uncorrelated noise and complex noise correlation coefficient (magnitude and phase). The measurement system is characterized in multiple steps. The reflection coefficient and the ENBW are independently characterized. The gain, the equivalent input noise, the emerging uncorrelated noise and the complex noise correlation coefficient are calculated with an optimization calibration. This calibration is based on the measurements and definitions of the equivalent hot standard and the different reflection standards at ambient temperature.

All calibration standards and calibration items are measured in one sequence. This sequence is repeated at least four times under different connector orientations in order to have statistical information and to account for drift effects of the measurement system.



4: Equivalent Hot Standard based on RF power. It consist of an RF-generator (not on the picture), a power-sensor (A), a power-splitter (B) and a 50 dB attenuator (C). The ENBW is related to the resolution bandwidth filter of the measurement system.



5: The measurement system for the comparison of the calibration items with the calibration standards consists of a spectrum analyzer (A) with an external low noise amplifier. In order to have a good sensitivity across the frequency range we need two external low noise amplifiers: One for frequencies from 10 MHz to 1 GHz (B) and one for frequencies from 1 GHz to 33 GHz (C).

Innovativer Kalibrierdienst für koaxiale Rauschquellen

In der Mobilkommunikation muss das Funksignal deutlich über dem Rauschen liegen, um eine Verbindung zwischen einem Mobiltelefon und einer Basisstation herzustellen. Daher ist es wichtig, den Rauschpegel genau zu messen. Nachdem das britische Metrologieinstitut (NPL) seinen primären Rauschkalibrierdienst 2018 einstellte, gab es (laut der Datenbank des BIPM) in Europa kein anderes Nationales Metrologieinstitut, das eine vergleichbare Kalibrierdienstleistung anbot.

Deshalb beschloss das METAS, einen eigenen Primärkalibrierdienst aufzubauen. Anstelle des traditionellen Verfahrens, das geheizte und/oder gekühlte Widerstände verwendet, setzt das METAS auf eine alternative Kalibriermethode: Das primäre Messnormal für die Rauschtemperatur basiert auf Hochfrequenz-Leistung.

Messungen der Hochfrequenz-Leistung sind am METAS gut etabliert. Deshalb waren bereits alle notwendigen Geräte vorhanden, um ein auf Leistung basierendes Messsystem einzurichten. Die Realisierung war mit vertretbarem Aufwand und ohne spezielle Rauschstandards möglich. Damit konnte der neue Primärkalibrierdienst bereits anfangs 2019 angeboten werden.

Service d'étalonnage innovant pour sources de bruit coaxiales

En communications mobiles, le signal radio doit être nettement supérieur au bruit, afin d'établir la connexion entre un téléphone portable et une station de base. Par conséquent, il importe de mesurer le niveau de bruit avec exactitude. Après la fermeture par l'institut de métrologie britannique (NPL) de son service d'étalonnage primaire du bruit en 2018, aucun autre institut national de métrologie ne proposait un service d'étalonnage comparable (d'après la base de données du BIPM).

C'est pourquoi METAS a décidé de mettre sur pied son propre service d'étalonnage primaire. Au lieu d'appliquer la procédure classique consistant à utiliser des résistances chauffées et/ou refroidies, METAS a misé sur une méthode d'étalonnage alternative: l'étalon primaire de la température de bruit repose sur la puissance haute fréquence.

Les mesurages de puissance haute fréquence étant bien ancrés à METAS, tous les dispositifs nécessaires à l'installation d'un système de mesure fondé sur la puissance étaient déjà en place. Il a été possible de le réaliser avec des moyens raisonnables et sans étalons de bruit spéciaux. Ainsi, METAS a pu proposer le nouveau service d'étalonnage primaire dès le début de l'année 2019.

Servizio di taratura innovativo per sorgenti di rumore coassiali

Nelle comunicazioni mobili, il segnale radio deve essere significativamente al di sopra del rumore per stabilire un collegamento tra un telefono cellulare e una stazione di base. Pertanto, è importante misurare con precisione il livello del rumore. Dopo che nel 2018 l'Istituto britannico di metrologia (NPL) ha cessato il suo servizio di taratura primaria del rumore, non c'era (secondo la banca dati del BIPM) nessun altro istituto nazionale di metrologia in Europa che offrisse un servizio comparabile di taratura.

Pertanto, il METAS ha deciso di istituire un proprio servizio di taratura primaria. Invece del metodo tradizionale, che impiega resistenze riscaldate e/o raffreddate, il METAS utilizza un metodo di taratura alternativo: il campione di misura primario della temperatura del rumore si basa sulla potenza ad alta frequenza.

Presso il METAS le misurazioni della potenza ad alta frequenza sono ben consolidate. Pertanto, tutte le apparecchiature necessarie per impostare un sistema di misurazione basato sulla potenza erano già disponibili. La realizzazione è stata possibile con uno sforzo ragionevole e senza utilizzare particolari standard di rumore. Ciò ha consentito di offrire il nuovo servizio di taratura primaria già all'inizio del 2019.