The Curious Mating Habits of Coaxial Connectors

Measuring transmission and reflection of microwave signals in coaxial lines is a key competence for research, development and maintenance of many products. The microwave connection between measurement instrument and device under test is nowadays the limiting factor in such measurements. METAS addressed this issue in two projects, Connector Modeling up to 70 GHz (CoMo70) and Calibration and Connectors (CalCon), in collaboration with a research institution and two industrial partners. The results of these studies are impressive and even require a revision of old principles in RF & MW metrology.

Johannes Hoffmann, Juerg Ruefenacht

In 2001, the US Federal Communications Commission (FCC) set aside the electromagnetic spectrum between 57 GHz and 64 GHz to be used for wireless communications (FCC part 15.255). Furthermore operation of equipment in this frequency band was declared as license-free, which is a major factor for commercial exploitation. This and the general trend towards higher frequencies in the telecommunication industry induced activity at the RF & MW Lab at METAS to extend the current upper frequency limit of its measurement services in coaxial lines from 50 GHz to 67 GHz.

Such a task required not only the acquisition of new equipment and putting the 1.85 mm connector (Box 2) into use. It was also clear that deviations from the ideal geometries and discontinuities do affect signal propagation in transmission lines increasingly at higher frequencies. From previous experience [1–3] it was known that the coaxial connector might act as a major discontinuity in the signal path and that its transmissive and reflective behavior should be investigated to obtain proper traceability up to 67 GHz.

Collaboration with Research and Industry Partners

Huber+Suhner, a Swiss connector manufacturer, asked for assistance with the characterisation of their new MMPX connector, which is applicable up to 67 GHz, too. These factors led to the start of the *CoMo70 project*. ETH Zurich was won for modeling the connector and for developing calibration algorithms which take the connector discontinuity into account. Huber+Suhner delivered samples of the MMPX and the 1.85 mm connector. Agilent Technologies, an American manufacturer of measurement instruments, participated as an advisor and provided blueprints of the connector and special components. METAS characterised connectors and components mechanically and performed electrical measurements.

1 The metrology grade 1.85 mm connector (male part on the left and female part with slotted inner conductor on the right) is applicable for frequencies up to 67 GHz. The diameters of outer and inner conductor are only 1.85 mm and 0.8036 mm, respectively. The small dimensions make this connector particularly delicate to handle.

The project started in 2006 and was successfully finished in 2009 [4]. The initial project goals were surpassed and the results confirmed that connector effects indeed need to be taken into account in accurate traceable RF & MW measurements at high frequencies.

Surprisingly, not all of the results coincide with intuition, and it turned out that even at lower frequencies connector effects might play a role. Triggered by these results, the project CalCon (Calibration and Connectors) was then started to extend the *CoMo70* activities to other connector families and to transfer the outcomes of *CoMo70* to metrological practice.

For this purpose, METAS employed the person, who worked during the *CoMo70* project as a PhD student at ETHZ, to optimally profit from the experience gained during *CoMo70* and for an efficient transfer of the previous results. The project is partially funded by the industrial partners Huber+Suhner and Agilent Technologies and is currently still going on. In the following we will give some insight in the curious mating habits of coaxial connectors and the consequences for RF & MW metrology.

History

For a layman it may be surprising that there is ongoing research about coaxial connectors which are known, produced and studied for more than 30 years. It may be even more surprising that research on connectors has barely begun. This is due to two reasons: For a long time, larger measurement uncertainties were acceptable, but nowadays industry demands increasingly smaller uncertainties, because these uncertainties often translate directly into revenue. This is related to the above mentioned tendency towards higher frequencies, which requires smaller structures and is more susceptible to mechanical

Coaxial connectors can be categorised into hermaphroditic connectors and sexed connectors. Sexed connectors can only be mated with connectors of the opposite sex. While mechanically not as complicated as hermaphroditic connectors, they can support higher frequencies. This fact made such connectors very popular in metrology and other applications.

7 mm, Type-N (7 mm), 3.5 mm, 2.92 mm, 2.4 mm, 1.85 mm and 1.00 mm connectors are relevant for metrological applications. The size refers to the diameter of the outer conductor and is the limiting factor in terms of applicable frequency. A 3.5 mm connector can be used up to 34 GHz, whereas a 1.85 mm connector can be used up to 67 GHz.

Above these frequency limits, unwanted higher modes of the electromagnetic field will start to propagate in the system. The diameter of the inner conductor on the other hand is determined by the characteristic impedance of the system, which is 50 ohms for most metrological applications. The sexed connectors can be subdivided into slotted connectors and slot-less connectors. This refers to the female contact which can be made with slots or without slots in the center conductor.

In the connector community there were and are still raging fights about the question: What is better, slotted or slot-less? The answer is simple. There is no better or worse, they are just different. Slotted connectors can have a lower reflection coefficient than slot-less connectors. On the other hand slot-less connectors can be characterised more accurately and are, therefore, the first choice for metrology applications.

In contrast to sexed connectors, hermaphroditic connectors can be connected to any other connector of the same type. The 7 mm connector is an example for a hermaphroditic connector. Such connectors are nowadays barely in use because they are expensive and have only a very limited frequency range.

2 Types of coaxial connectors.

features. Secondly, the accurate characterisation of coaxial connectors requires mechanical measurement capabilities and computation power which only recently became available.

Characterisation of Coaxial Connectors

Metrology grade coaxial connectors are mechanically and theoretically highly complex objects. Mechanically they are complex because connectors feature extremely tiny spring contacts, which are manufactured in such a way that about 3000 connections can be made before the connector is worn out and has to be replaced or serviced. Due to the tight mechanical tolerances required, such connectors cost about 1000 US$ a piece.

This price and the fragility of the devices restrict the handling of devices equipped with such connectors to experienced operators. Moreover, the connector needs to be seen as a discontinuity in the signal path, which creates reflection. This brings up the theoretical part of connectors. As for the characterisation of such behavior it is necessary to determine the scattering parameters (S-parameters, see Box 3) of the connector as a function of its mechanical dimensions.

S-parameters of a Complete Connector

The amplitude of the reflection from the connector depends mainly on its size and shape. The connector can be considered as a rather short and small discontinuity, which allows accurate computation of its amplitude and phase of reflection. This is done with an electromagnetic field simulator (Box 4). Essentially, such a program breaks the whole electromagnetic problem of a connector down to many smaller problems which are interconnected, but which can be solved by directly applying Maxwell's theory. The result is the electromagnetic field in the connector, based on which the S-parameters of the connector can be derived.

S-parameters are always computed at a reference plane and are defined with respect to the fundamental mode (TEM mode) of wave propagation. Discontinuities have the unpleasant property to locally excite higher modes, which decay with distance from the discontinuity. Thus, the reference plane for the S-parameter calculation is selected to be far enough away from the discontinuity such that higher modes of the field have attenuated sufficiently.

By placing reference planes (illustration 5) in appropriate distance from the connector, one can compute its reflection and transmission coefficients with high accuracy. Now a virtual reference plane (illustration 5) can be introduced. The S-parameters at the virtual reference plane are computed by subtracting the piece of coaxial line between virtual reference plane and reference plane. Such virtual reference planes can be placed at the start and end of the connector. The S-parameters at these virtual reference planes are the S-parameters of the connector [5].

S-parameters of a Half-Connector

As already stated, the real reference plane has to be sufficiently far away from any discontinuity for the successful definition of S-parameters. This is in direct contradiction with the definition of S-parameters when they are measured with a vector network analyser (VNA), which requires a reference plane that is in the center of the connector (illustrations 6 and 7). To rescue the definition of VNA S-parameters, one uses the concept of the perfect port, which is a semi infinite piece of coaxial line with nominal 50 ohm impedance.

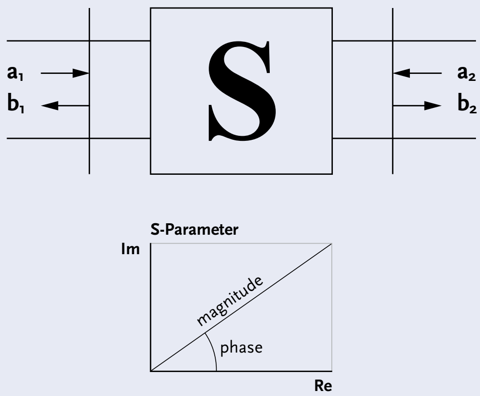
Since coaxial connectors rarely appear always as the same pair, it is necessary to find a way to characterise a male or a female connector individually. Therefore we need to introduce the concept of the half-connector. The S-parameters of a half-connector are computed by simulating the electromagnetic fields of a connector, where the second half is replaced by a perfect port. Obviously one can do this for the male part and for the female part (illustrations 6 and 7).

Again the real reference plane has to be sufficiently far away from any discontinuity, and again virtual reference planes are used to shift the S-parameters to the start and end of each half-connector. Now the two resulting sets of «half S-parameters» can be cascaded and compared to the «complete S-parameters» of the full connector. Ideally they should be the same, but in reality they are not. The disagreement between the cascaded «half S-parameters» and the «complete S-parameters» is part of the final measurement uncertainty. It depends very much on the design of the female part and on the size of the pin gap (illustration 5), how similar these two pairs of S-parameters are.

S-parameters are used to characterise reflective and transmissive behaviour of a device upon impact of a high frequency electromagnetic signal. The illustration schematically represents the situation for a two-port device (e.g. an attenuator) with input signals applied to both ports. If the device is linear, the output signals can be defined in terms of the input signals. Thus,

$$\mathbf{b_1 = S_{11}a_1 + S_{12}a_2}$$
$$\mathbf{b_2 = S_{21}a_1 + S_{22}a_2}$$

with the signal amplitudes $\mathbf{a_1}$, $\mathbf{a_2}$, $\mathbf{b_1}$ and $\mathbf{b_2}$ and the scattering parameters $\mathbf{S_{ij}}$. The scheme can be generalised to n ports and the equations can be written more economically in matrix form $\mathbf{b = S \cdot a}$ with the S-parameters contained in the scattering matrix **S** and the column vectors **a** and **b** containing input and output signal amplitudes, respectively. S-parameters are two-dimensional quantities either described in polar coordinates with magnitude and phase or as complex numbers with real **(Re)** and imaginary **(Im)** parts. They can be measured with vector network analysers.



3 Scattering Parameters (S-Parameters).

If the pin gap is too small, the S-parameters of a complete pair and the cascaded S-parameters differ by a significant amount. This is because too small pin gaps provoke resonances between the male and female part. These resonances are highly sensitive to sub-µm changes in the pin gap. In practice, such small dimensional variations can neither be measured nor controlled. Thus the S-parameters of a complete connector with extremely small pin gap cannot be modeled with high accuracy and the connector cannot be divided in half-connectors (figures 8 and 9).

In this case, the connector is not useful for metrology applications. Too small pin gap means less than 5 µm for the 1.85 mm connector (figures 8 and 9). The insight that the pin gap needs to have a certain size to ensure reproducible S-parameters is one of the main outcomes of the *CoMo70* project [6]. Now, one might be tempted to say that generally a larger pin gap is better than a small one. This is not true either because the larger the pin gap is the stronger the reflection gets, which is undesirable. It was found that the optimum pin gap is 7 µm to 10 µm for 1.85 mm connectors. This result breaks with an old paradigm in RF & MW metrology, which advocates to keep pin gaps as small as possible.

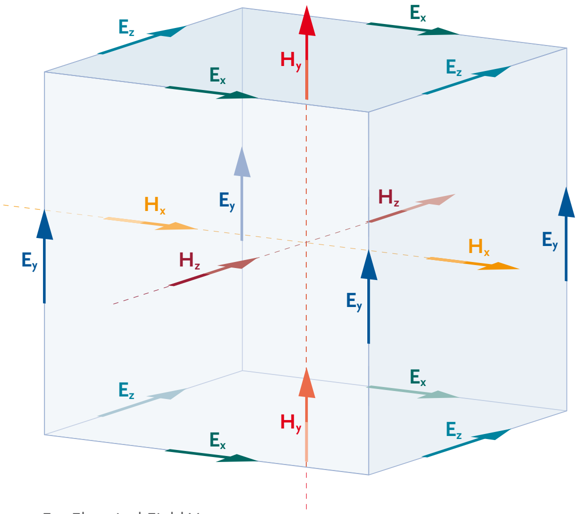
Input Parameters and Traceability

Highly accurate mechanical dimensions of the connector are needed for its electromagnetic modeling. Measuring dimensions of very small objects like connectors with an accuracy of less than 1 µm is a very demanding task. The dimensional metrology group at METAS has unique measurement capabilities thanks to its micro coordinate measuring machine µCMM [7]. The accuracy in these measurements is limited by the design and the surface quality of the connector.

The mechanical accuracy can be translated into electrical accuracy with appropriate modeling tools and techniques. Thus the measurement of the S-parameters is traced back to the SI units meter, second, kilogram and ampere and requires the measurements of the dimensions and the conductivity of the connector, the modeling of the electromagnetic fields in the connector and finally the computation of reflection and transmission coefficients.

VNA Calibration and Coaxial Standards

A VNA needs to be calibrated with known coaxial standards before it can be used for S-parameter measurements. Calibration consists of connecting the known standards to the VNA and measuring their raw S-parameters. From the raw S-parameters and the assumed values of the standards one can compute the error coefficients of the model describing the VNA.



Electromagnetic simulation aims at applying Maxwell's equations to a non-trivial problem. Nowadays mainly two methods are used: Finite element frequency domain simulation and finite difference time domain simulation. The methods differ in the kind of input signals they can process. E.g. time domain methods can process nearly any given input signal of finite duration. In contrast frequency domain methods can process only input signals of one single frequency and infinite duration. Obviously both methods are interconnected by Fourier and Laplace transforms.

For finite difference time domain simulations, the computational domain is subdivided in hexaeders. The electric field in one hexaeder is assumed to be linearly dependent on location. Thus the electric field can be stored as the voltage over each edge of the hexaeder. In parallel, a second mesh is imposed for the magnetic field. It is complementary to the electric field mesh. Thus the edges of the magnetic field hexaeders go through the areal centers of the electric field hexaeders.

Assuming again linear dependence on location, the magnetic field can be stored as magnetic voltages over the edges of the second grid. These electric and magnetic voltages are intermittently updated according to Maxwell's equations. This means the input signal is subdivided in small time steps and the according electrical voltages, the magnetic voltages, electric, magnetic ... and so on are computed. This yields the electromagnetic fields over time. By Fourier transformation they can be transformed to frequency domain and finally to transmission and reflection coefficients, e.g. S-parameters.

For finite element frequency domain, the computational domain is subdivided into tetraeders. In each tetraeder one defines several electromagnetic field configurations, which are called base functions. As a next step, these base functions are subjected to a Maxwell operator and multiplied with weighting functions. These equations are then integrated over the whole computational domain.

By exchanging the multiplied weighting function one can generate as many linear equations as there are base functions and tetraeders. The result is a system of linear equations where the electromagnetic sources are a constant vector and the coefficients of the base functions are the variables. The solution of the linear system will give the coefficients of the base functions and thus the electromagnetic field in the connector. Again, one can compute transmission and reflection coefficients from the electromagnetic fields.

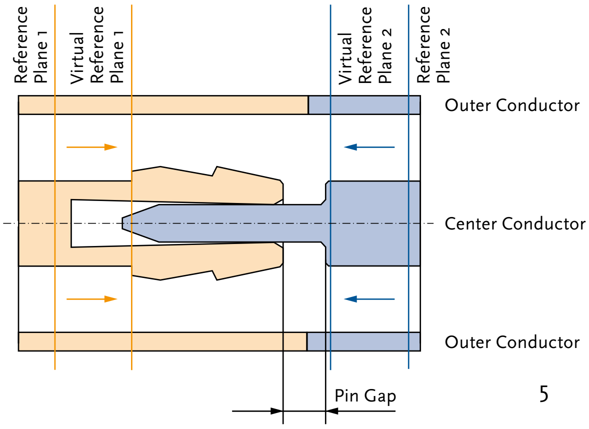
4 Simulation technology: In the Yee scheme (see picture above), the represented quantities are electric and magnetic fields integrated over one grid length. Electric and magnetic field are staggered.

Based on the types of standards used, different calibration schemes are available. The aim of calibration is to define measurement planes at the VNA ports with a reference impedance of typically 50 ohms. The knowledge of the S-parameters of the standards has a direct impact on the accuracy of any subsequent measurement with the VNA. Coaxial transmission lines (air lines) of different length [8] and short circuits are typical standards for line reflect line (LRL) calibrations.

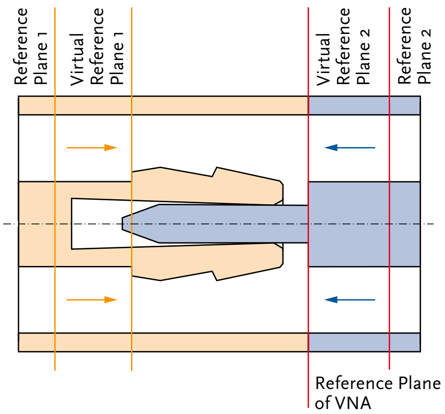
A practical measurement problem during LRL calibrations is related to the use of air lines with center conductors that are not self-supporting. The center conductor of such a mounted airline is hold in position by the connectors of the adjacent VNA ports but its longitudinal position is not entirely fixed. The resulting pin gap is arbitrary and varies from one connection to the next. With the above mentioned impact of the pin gap in mind, it is obvious that this will lead to inconsistencies and problems with LRL calibrations, as has been observed and reported in the past. It turns out that the pin gap needs to be controlled to obtain consistency between different calibration schemes. An in-depth study of a possible solution to the problem is currently underway [9].

Another calibration method uses offset shorts, e.g. short circuits with pieces of coaxial line attached in front of the short circuit plane. This offset short (OS) calibration [10] and the LRL calibration are examples of primary calibrations which provide direct traceability to SI units.

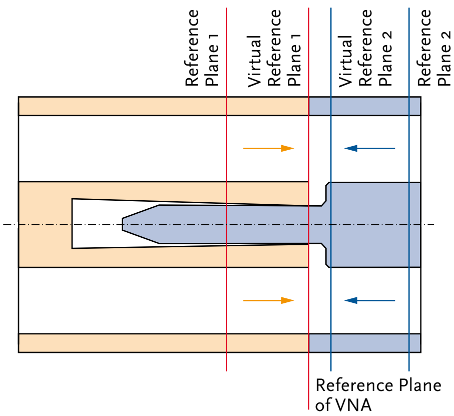
The S-parameters of LRL and OS standards can be calculated from dimensional measurements and known material properties. Within the *CoM070* project, this has been done for the above mentioned standards by taking the half-connector of the standard into account. The mechanical characterisation of the



5



6



7

5 Longitudinal cross section of a coaxial connector with outer conductor and center conductor parts in yellow (female) and blue (male). The virtual reference planes are derived from the reference planes.

6 A female half-connector with perfect port on the right side. The reference plane of the VNA is described by the virtual reference plane 2.

7 Male half-connector with perfect port on the left side. The VNA reference plane is described by the virtual reference plane 1.

standards, including their half-connectors, is done with a laser gauge system and an air gauge system for diameter measurements and the µCMM coordinate measuring system for general length measurements. The µCMM system is used as well for diameter measurements in the end zones of the line where the air gauging system does not work.

The approach for modeling the standards is to cut the standard into small slices along its length. The S-parameters of these slices are computed and finally cascaded. This approach can be used to characterise coaxial lines and offset shorts. Thus two independent sets of standards for 1.85 mm calibration are available. This increases the confidence in the calibration and provides at the same time insight into the involved uncertainties.

The VNA calibration algorithm is based on a set of nonlinear equations, which needs to be solved for the model parameters of the VNA. Advanced calibration schemes do this in an over-determined way in the sense that the number of measured standards is larger than the number of unknowns in the system of equations. Uncontrollable and unknown effects and errors in the definition of standards and in the model of the VNA are represented by random variables. The solution of the system is an appropriate statistical estimator of these random variables based on numerical optimisation.

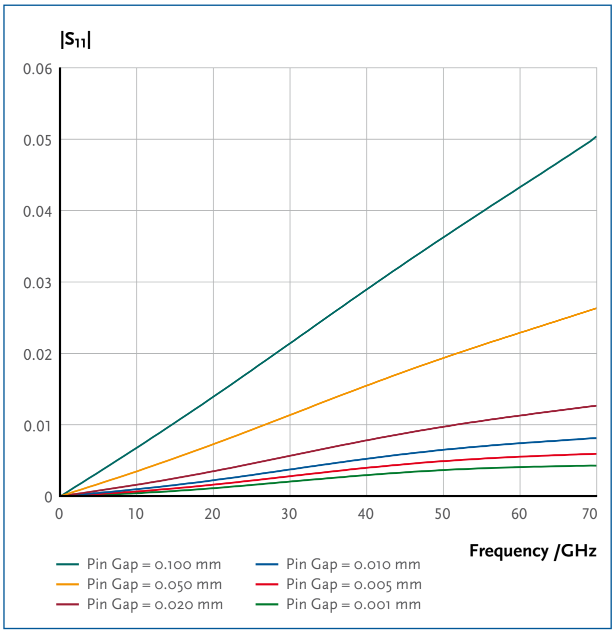
Uncertainties arise most notably from the characterisation of the standards, but also from environmental influences, device imperfections and measurement setup. Another major outcome of the *CoMo70* project was an improved over-determined calibration algorithm [11], which will not be discussed further here.

Change of Paradigm

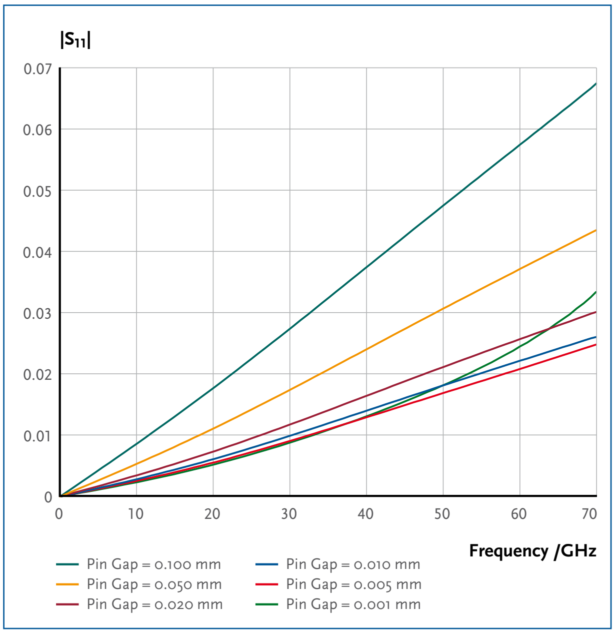
From the comparison between different VNA calibration procedures, notably line based calibration and offset short calibration, it became obvious that connector effects need to be accounted for. The connector has to be part of the definition of the calibration standard. This has a non-negligible impact on the S-parameters of a standard. E.g. in the case of 2.4 mm female half-connectors it was found that their S_{11} is about 0.01 to 0.02 [5]. This is significant compared to the uncertainties which are typically declared at the level of national metrology institutes. For male standards, the effect was found to be less pronounced.

Discrepancies that have been observed in the past between different calibration schemes can now be explained with the neglect of connector effects and an inconsistent definition of the reference plane [5]. While these effects become more dominant with higher frequency, it was also found that even at lower frequencies connector effects can play a role. This is one of the reasons why the follow-up project *Calibration and Connectors (CalCon)* was started.

Two main lessons have been learned for VNA metrology: First it is necessary to include the connector in the definition of the coaxial standard; otherwise it will not be possible to define a



8 Absolute value of reflection coefficient of a 1.85 mm connector plotted as a function of frequency. The connector under consideration is useful for metrology applications because its reflection coefficients scale nicely with the pin gap.



9 The same as figure 8 for a 1.85 mm connector with larger chamfers in the design of the female connector interface. The connector under consideration is not useful for metrology applications because its reflection coefficient reveals behavior close to resonance for the 0.001 mm pin gap.

consistent reference plane for S-parameter measurements. Second it is necessary to control the pin gap during the measurement process, otherwise the results will not be reliable. The *CoMo70 project* has laid the foundation to tackle these issues with the help of mechanical characterisation, electromagnetic field simulation and with the concept of the half-connector. The findings of *CoMo70* will require the other national metrology institutes to either take connector effects more seriously and to start their own investigations or to revise their claimed VNA measurement uncertainties.

New Measurement Services

As a result of both projects, METAS is now one of the very few national metrology institutes worldwide which offer measurement services in 1.85 mm coaxial lines. Thanks to the experience and knowledge gained together with the external partners during the project work, an improved and solid traceability chain has been established. The transfer of this competence to measurement service is still underway, but already now METAS can offer very small measurement uncertainties for these measurements. For more information refer to www.metas.ch/como70

References

[1] J. Furrer: Die Tücke steckt im Stecker, METinfo, Vol. 10, Nr. 1, pp. 10–16, 2003.
[2] B. Szentkuti, M. Wollensack, J, Ruefenacht: Zur Implementierung der Doppelkorrekturmethode bei METAS, METAS-Bericht 2003-250-507_v02, 2007.
[3] J. Ruefenacht: Connector problems and their mechanical and electrical characterisation, 24th ANAMET meeting, September 2005.
[4] J. Hoffmann: Traceable S-parameter measurements in coaxial transmission lines up to 70 GHz, Dissertation ETH no. 18593, October 2009.
[5] J. Hoffmann, P. Leuchtmann, J. Ruefenacht, K. Wong: S-parameters of Slotted and Slotless Coaxial Connectors, 74th ARFTG Conference, Boulder, Conference Digest, Vol. 74, December 2009.
[6] J. Hoffmann, P. Leuchtmann, R. Vahldieck: Pin Gap Investigations for the 1.85 mm Coaxial Connector, IEEE European Microwave Week, Munich, Proceedings, pp. 388–391, October 2007.
[7] A. Kueng, F. Meli, R. Thalmann: Ultraprecision micro-CMM using a low force 3D touch probe, Measurement Science and Technology, Vol. 18, no. 2, pp. 319–327, January 2007.
[8] J. Ruefenacht, P. Leuchtmann: Air Lines Make Impedance Traceable to SI Base Units, METinfo, Vol. 9, Nr. 2, pp. 7–15, 2002.
[9] J. Hoffmann, J. Ruefenacht, M. Wollensack, M. Zeier: Comparison of 1.85 mm Line Reflect Line and Offset Short Calibration, submitted to 76th ARFTG Conference, Clearwater Beach FL, December 2010
[10] J. Hoffmann, P. Leuchtmann, R. Vahldieck: Over-determined Offset Short Calibration of a VNA, 71st ARFTG Conference, Atlanta, Conference Digest, Vol. 71, June 2008.
[11] J. Hoffmann, P. Leuchtmann, J. Ruefenacht, R. Vahldieck: A stable Bayesian vector network analyzer calibration algorithm, IEEE Trans. Microwave Theory Tech., Vol. 57, Issue 4, pp.869–880, April 2009.

Dr. Johannes Hoffmann (left), direct phone +41 31 32 34 716,
johannes.hoffmann@metas.ch, and Juerg Ruefenacht,
direct phone +41 31 32 33 493, juerg.ruefenacht@metas.ch.

Das wundersame Paarungsverhalten koaxialer Verbinder

Die Messung von Transmission und Reflexion von Hochfrequenzsignalen in koaxialen Leitungen ist ein wichtiger Aspekt in der Erforschung, Entwicklung und im Unterhalt vieler Produkte. Die HF-Verbindung zwischen dem Messinstrument und dem Prüfling ist heutzutage oft der limitierende Faktor bei dieser Art von Messungen. Das METAS hat sich in Zusammenarbeit mit einem Forschungsinstitut und zwei Industriepartnern dieser Problematik in zwei Projekten angenommen, Connector Modeling up to 70 GHz (CoMo70) und Calibration and Connectors (CalCon). Die Resultate dieser Untersuchungen sind wegweisend und werden dazu führen, dass althergebrachte Prinzipien in der Hochfrequenzmetrologie revidiert werden müssen.

Bezüglich der Verbindereffekte in exakten HF-Messungen wurden folgende Erkenntnisse gewonnen: Erstens muss der Verbinder bei der Definition von Kalibrierstandards berücksichtigt werden, sonst ist es nicht möglich, eine konsistente Referenzebene für S-Parameter-Messungen zu definieren. Zweitens muss der Pin Gap während der Messung unter Kontrolle sein, sonst ist das Ergebnis nicht verlässlich. Die Projekte CoMo70 und CalCon haben die Voraussetzungen geschaffen, um diese Problematik mit Hilfe von mechanischer Charakterisierung, elektromagnetischer Simulation und mit dem Konzept des Halb-Verbinders zu bewältigen.

Das METAS ist eines von wenigen Labors weltweit, das HF-Dienstleistungen für das 1.85 mm Koaxialsystem bis 67 GHz anbietet. Als ein Resultat beider Projekte kann das METAS sehr kleine Messunsicherheiten anbieten (www.metas.ch/hf).

Le comportement surprenant des connecteurs coaxiaux

La mesure de la transmission et de la réflexion des signaux haute fréquence dans des conducteurs coaxiaux représente un aspect important de la recherche, du développement et de l'entretien de nombreux produits. La connexion HF entre l'instrument de mesure et l'échantillon est actuellement le facteur limitatif pour ce type de mesures. En collaboration avec un institut de recherche et deux partenaires industriels, METAS consacre deux projets à cette problématique : Connector Modeling up to 70 GHz (CoMo70) et Calibration and Connectors (CalCon). Les résultats de ces travaux sont probants et mettent en lumière la nécessité de revoir les principes traditionnels de la métrologie haute fréquence.

S'agissant des effets des connecteurs dans les mesures HF de haute précision, les résultats suivants ont été obtenus: il s'agit d'une part de tenir compte du connecteur dans la définition des étalons, afin de pouvoir définir un niveau de référence cohérent pour les mesures de paramètres S. D'autre part, le pin gap doit être sous contrôle pendant la mesure, afin de garantir la fiabilité du résultat de mesure. Les projets CoMo70 et CalCon ont créé les conditions nécessaires pour traiter cette problématique à l'aide de la caractérisation mécanique, de la simulation électromagnétique et avec le concept du semi-connecteur.

METAS est l'un des rares instituts nationaux de métrologie qui offrent au niveau mondial des prestations de services HF pour des systèmes coaxiaux à connecteur 1.85 mm allant jusqu'à 67 kHz. Grâce à ces deux projets, METAS est en mesure d'offrir des très petites incertitudes de mesure (www.metas.ch/hf).

Il comportamento singolare dei connettori coassiali

La misura della trasmissione e della riflessione dei segnali in alta frequenza nei connettori coassiali rappresenta un aspetto importante nel campo della ricerca, dello sviluppo e della manutenzione di numerosi prodotti. Il controllo tramite la connessione HF tra lo strumento di misurazione e il campione di prova è attualmente il fattore limitante per questo tipo di misure. Insieme ad un istituto di ricerca e due partner industriali, il METAS si occupa di questa problematica attraverso due progetti: Connector Modeling up to 70 GHz (CoMo70) e Calibration and Connectors (CalCon). I risultati emersi dai lavori sono eloquenti e provano che occorre rivedere i principi tradizionali della metrologia ad alta frequenza.

Riguardo agli effetti dei connettori nelle misure ultraprecise in alta frequenza, sono emersi i seguenti risultati: de una parte occorre tener conto del connettore nella definizione dei campioni, affinché un livello di riferimento coerente per le misure dei parametri S possa essere definito. D'altra parte il pin gap deve rimanere sotto controllo durante la misura, in caso contrario il risultato di misura non sarebbe affidabile. I progetti CoMo70 e CalCon hanno creato le condizioni necessarie per superare questa problematica mediante caratterizzazione meccanica, simulazione elettromagnetica e col concetto del semi-connettore.

Il METAS è uno dei pochi istituti nazionali di metrologia a livello mondiale che sono in grado di offrire prestazioni HF per sistemi coassiali a conduttori con diametro di 1,85 mm fino ad una frequenza massima di 67 GHz. Grazie ai progetti, il METAS è in grado di offrire ora incertezze di misurazione piccolissime (www.metas.ch/hf).