RF Training Kit

With the migration of communication systems to higher frequencies, signal integrity plays an increasingly significant role in the design process. This in turn puts more demand on the test and measurement systems with improved capabilities. For a manufacturer of RF connectors and cable assemblies, a thorough understanding of electromagnetic phenomena is critical to establishing design rules to eliminate adverse effects. Return loss, insertion loss and the time domain behaviour of these products have to be kept under control from design, production, and assembly to final testing.

Increasingly, it is not seen as being sufficient for companies to use calibrated vector network analyzers and calibration kits for final testing to run an effective and high quality production line. The knowledge of negative effects that can arise in a production and assembly line needs to be shared with all relevant departments and subsidiaries. From this premise the idea was born to design an educational RF training kit for company internal purposes with devices that clearly and purely demonstrate the single effects supported by tutorials. However, this educational kit is not only available for internal use but also for academic and industrial customers.

The kit (order number 99M007-000) includes: coaxial devices with adapters; circuit board with 15 microstrip structures; documentation covering basic circuit theory up to sources of reflections, losses and crosstalk; guided exercises for experiencing these effects using the kit hardware on a vector network analyzer (VNA); and PowerPoint slides and field animations supporting the exercises.

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COAXIAL DEVICES

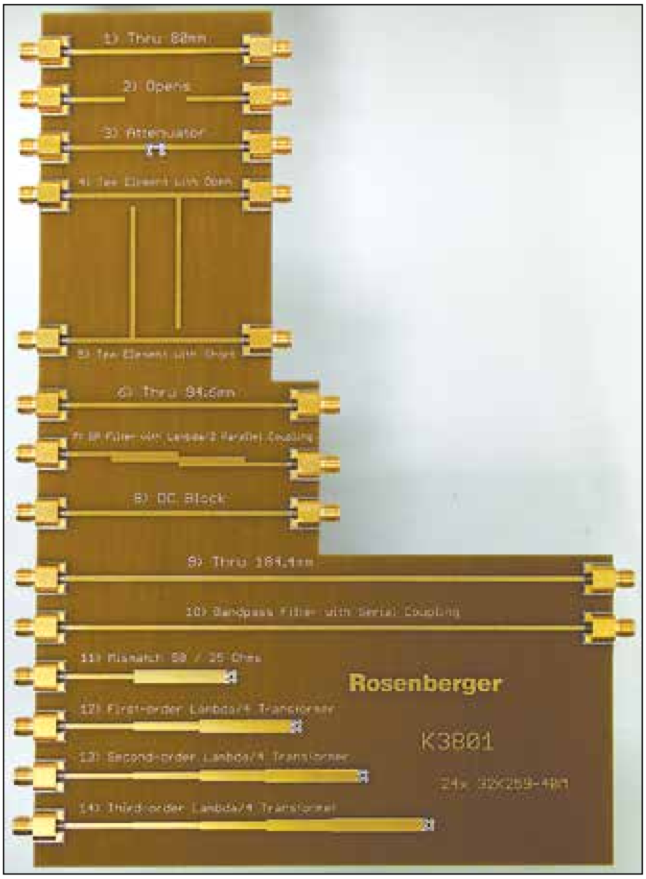
The primary coaxial device is a 100 mm unbeaded gold plated air line with male and female RPC-N 50 Ω connectors. It consists of one outer conductor and five inner conductors with different diameter geometries. Combining the outer conductor with an inner conductor that results in a homogeneous 50 Ω air line represents the coaxial device with the lowest reflections and the lowest specific losses available. Connected to a calibrated VNA, it shows the measurement limits for further exercises.

▲ *Fig. 1 Adapter with a damaged finger.*

By replacing the inner conductor by a thinner one and adding PTFE beads over the whole length also results in a 50 Ω coaxial line. A higher insertion loss than before can be observed caused by additional dielectric losses and the line becomes electrically longer. In addition these beads can be replaced by similar ones which have a flattened outer diameter. This causes a reduction in the usable operating frequency for the quasi TEM mode.

With a set of small PTFE beads, diameters of 4, 5 and 6 mm and length of 2, 3, 5, 8 and 10 mm, discontinuities in cable assemblies can be simulated very well, e.g., regular discontinuities on a coaxial cable result in narrowband resonances. With a selection of different PTFE beads, experimentation with other bead configurations is possible. This is ideal for exploring the impact that the transformation parameters, set by the user on the VNA, have on the measurement results.

Time domain measurement is mainly limited by the rise time of the measurement system. On VNAs, this is inversely proportional to the upper measurement frequency, often limited by the connector system or the cable material used. When measuring with a long rise time, discontinuities separated by a short distance cannot be distinguished and the real impedance of a short discontinuity can't be measured.



▲ *Fig. 2 Circuit board with 15 microstrip circuits.*

Besides the air line, the coaxial devices of this kit are complemented by two special RPC-N 50 Ω adapters. They were designed to demonstrate possible assembly problems in a production line. One adapter with a radial stub in the outer conductor, the other with one of the six female contacts fingers lifted off, as shown in ***Figure 1***. It is known as an 'adapter damaged finger' and is a nightmare for quality departments.

MICROSTRIP CIRCUITS

On the circuit board, shown in ***Figure 2***, several circuits are implemented with female SMA interfaces. There are 50 Ω transmission lines of different length. Compared to the coaxial air line significant higher specific losses can be measured. A Π-type attenuator is realized with SMD resistors. The frequency response of the insertion loss and the return loss gives an idea of the useable frequency range. Filter structures are available as an opened stub, a shorted stub, a DC block and bandpass filters with serial/parallel coupling. Finally, three quarter-wave transformers, from first to third order, demonstrate narrow to medium bandwidth low loss transformers.

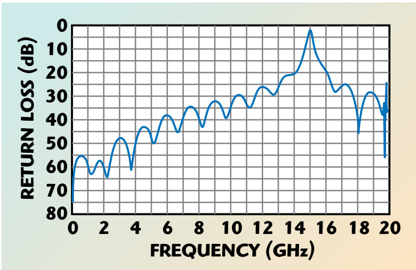
DOCUMENTATION

The included documentation covers the basics of electrical engineering: Electromagnetism, DC circuit theory, complex analysis, AC circuit theory, transmission line theory, losses, reflections and coupling.

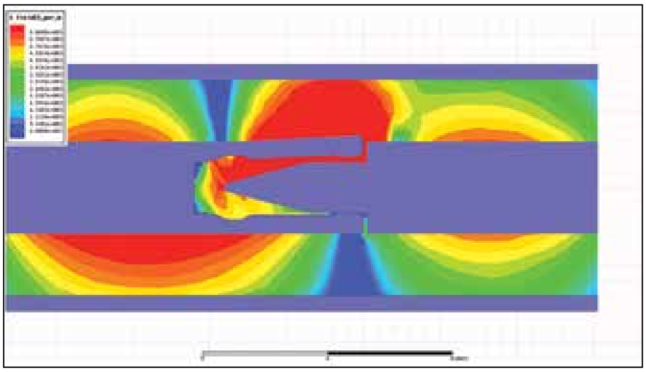
EXERCISES

To work most effectively with the coaxial and planar devices, an extra document with comprehensive exercises is included. The document starts with handling precautions, especially for the unbeaded air line. The exercises require the user to have the necessary knowledge of the setup and handling of the VNA. Every exercise includes a description of the training kit equipment needed and gives directions for parameters to measure.

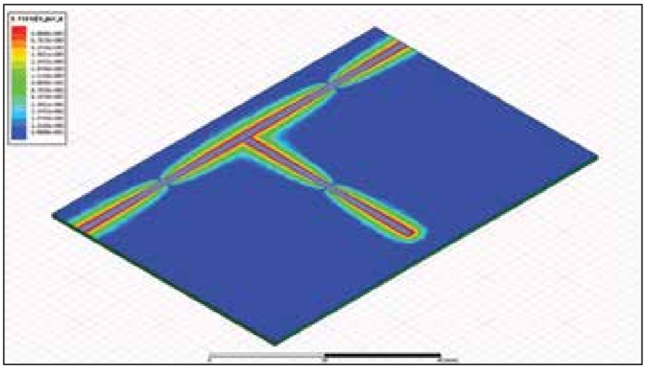
Questions regarding the measurement results aid the user in understand-



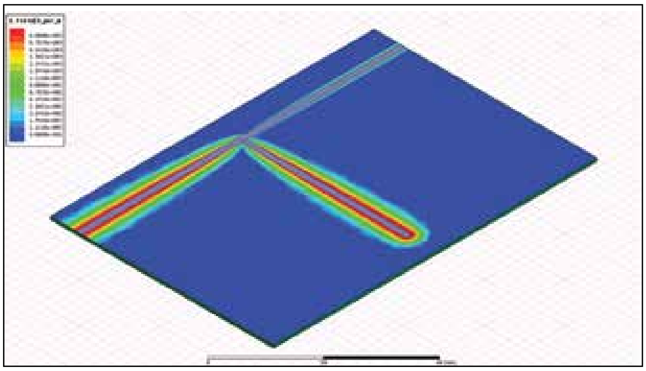
▲ *Fig. 3 Return loss for the adapter with a damaged finger.*



▲ *Fig. 4 Field simulation for the adapter with a damaged finger.*



▲ *Fig. 5 Field simulation of a transmission line with opened stub, transmissive at 2 GHz.*



▲ *Fig. 6 Field simulation of a transmission line with opened stub, reflective at 1 GHz.*

ing the effects. Also, with references to the single chapters of the tutorial and references to the simulations and field animations the understanding can be enhanced. Depending on the skill level and on the time available, specific exercises can be omitted.

REFERENCE SIMULATIONS AND FIELD ANIMATIONS

Every exercise is supported with reference simulations of the return loss, the insertion loss, the time domain response and an animation of the electric field for the whole device or in part when necessary. Especially for beginners it's very interesting and instructional to see what happens when the wavelength equals the distance between two or more discontinuities.

The tremendous impact discontinuities have is clearly shown in the 'adapter damaged finger' exercise. The frequency response and the field animation at 15 GHz are shown in ***Figure 3*** and ***Figure 4***.

Figure 5 shows the field plot of the transmission line with opened stub at 2 GHz where it is transmissive. At 1 GHz the same structure becomes reflective and nearly no signal passes through the structure. The field plot, shown in ***Figure 6***, demonstrates how the opened stub is transformed into a short at λ/4.

This kit which included special components was designed for company internal training and for academic and industrial education to enable a closer look into RF connector and cable assembly design and production. In Rosenberger's experience, this training kit is ideal for a hands-on approach to understanding the major causes of signal degradation on a system.

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