A New Calibration Kit for VNA Measurements of General Microstrip Line Devices Using Gap Waveguide Technology

(article starts on next page)

A New Calibration Kit for VNA Measurements of General Microstrip Line Devices Using Gap Waveguide Technology

Julius Petersson, Ashraf Zaman, Jian Yang
Department of Electrical Engineering, Chalmers University of Technology
Chalmersplatsen 4, Gothenburg, Sweden

***Abstract* – A new calibration kit for VNA Measurements of general microstrip line devices is presented. The proposed calibration kit and test fixture is based on a gap waveguide to microstrip transition which can provide an interface for measurements on microstrip line devices with low influence on the DUT performance due to its compact size.**

***Index Terms* — VNA measurement, TRL calibration.**

1. Introduction

With the coming of 5G wireless communication systems and other systems such sensor system, car anti-collision radar systems, imaging systems, millimeter wave (mmWave) systems and devices become more and more widely used [1]. Due to the physical sizes of such mmWave devices, it is always a challenge to do the accurate and easy measurements, especially for antenna systems. Current popular GSG probes for mmWave microstrip line devices are relatively large in size compared to microstrip circuits and antennas. This may lead to measurement errors that does not correspond to the device under test (DUT) in an environment free of influence. In addition, GSG probes require good contact, which imposes a high requirement on the DUT to have very good contacting surface in order to avoid any possible damage to the expensive GSG probes. Therefore, it is important and demanded to find alternative smaller structure for mmWave measurement without the above mentioned disadvantages. In this paper, a new calibration kit based on a groove gap waveguide to microstrip transition is introduced and a preliminary design of the kit with simulations on the performance of one example is presented.

2. Test fixture

The measurement kit uses a compact transition presented in [2] as the connection structure between measurement instrument such as Vector Network Analyzer (VNA) and a DUT of microstrip type, where the gap waveguide and the microstrip line lies in the same plane without any physical conductive contact (such as wire bonding or probe needle contact). The transition consists of a cavity backed probe which couples the energy from the groove gap waveguide to the microstrip line seen in Fig. 1. Port 1 is a standard rectangular waveguide, while port 2 is a microstrip line which extends out of the measurement kit fixture, where the device under test can be placed and measured under low influence from the test fixture. The test fixture is very compact and can be made as small as 2λ x 1λ x 3λ (W x H x L), where λ is the wavelength at the operation frequency.

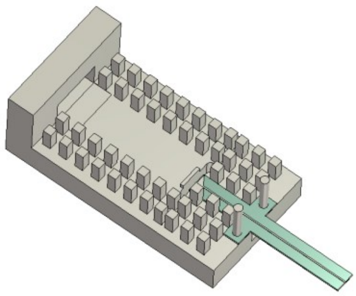

Fig. 1. The new measurement kit fixture.

The transition is modified to work with solderless attachment of the PCB to the test fixture with alignment pins and pins underneath the PCB to stop any wave propagation that may arise between the PCB ground plane and test fixture.

The performance of the transition is slightly worse when the PCB is transitioned from the narrow groove gap waveguide to free space compared to the back–to–back transition simulations where the groove gap waveguide enclosed the entire microstrip section. Simulations on a back–to–back transition scaled for the WR15 sized waveguide are shown in Fig. 2. The reflection coefficient is not of crucial importance as the effect of the transition will be removed by the calibration, but the higher reflection coefficients in the low and high parts of the waveguide band may lower the dynamic range of the measurements.

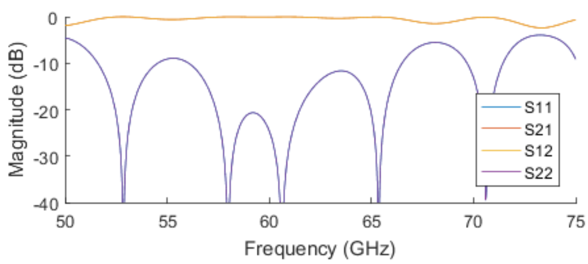

Fig. 2. Back to back transition s-parameters.

3. Calibration circuits

The TRL-algorithm (Thru-Reflect-Line) is used to remove the effect of the transition and move the reference plane to the device under test as described in [3]. The algorithm requires three measurement standards, shown in Fig. 3: A through transmission line with zero added length, a reflect standard with a short at the reference plane with high reflection coefficient at and a line standard with an added length between the reference plane. The measurement system can be represented with the transmission matrices

$$T_m = T_A \, T_{DUT} \, T_B \qquad (1)$$

where T_m is the complete system as seen from the VNA, T_A and T_B are the error boxes representing the transmission from the VNA to the reference plane and T_{DUT} the actual DUT. The TRL-algorithm solves T_A and T_B with the calibration standards and we get the transmission matrix for the DUT with

$$T_{DUT} = (T_A)^{-1} \, T_{DUT} \, (T_B)^{-1} \qquad (2)$$

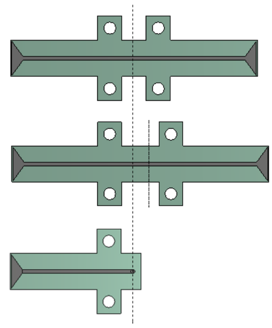

Fig. 3. Calibration standards with dashed reference plane.

4. Calibration proof of concept

A measurement of a microstrip line filter is simulated in CST to evaluate the calibration kit. Simulated s-parameters of the calibration standards are used with the TRL-algorithm to move the reference plane from the waveguide port on the test fixture to the microstrip line. The simulated s-parameters for the embedded and deembedded S-parameters can be seen together with direct simulations at the reference plane in Fig 5 and 6. The difference in magnitude between the embedded and deembedded simulations is less than 1 dB and the phase error is less than 5 degrees over the entire waveguide band.

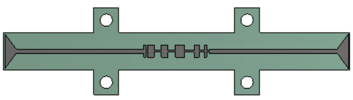

Fig. 4. Filter DUT.

5. Conclusion

The simulations show that the new non-contact waveguide-to-microstrip-line transition base on gap waveguide technology with calibration kits can be used as a small sized measurement structure to measure general microstrip line devices. The calculated results show promising performance of the test fixture over the entire waveguide bandwidth, even with the slightly worse transition performance since the calibration process can calibrate it out. The next step will be manufacturing prototypes to test the calibration outside computer simulations. The contactless waveguide-to-microstrip-line transition used in this new measurement setup has been protected by a pending patent **Error! Reference source not found.**.

Acknowledgment

This work is carried out partially within the Strategic Innovation Program ”Smarter Electronics Systems”, a joint venture of Vinnova, Formas and Energy Agency, with a grant no. 2017-01881.

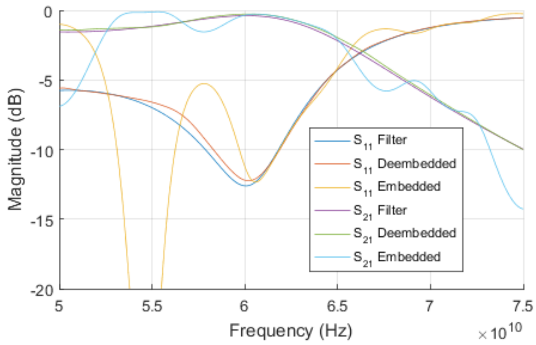

Fig. 5. DUT S-parameters.

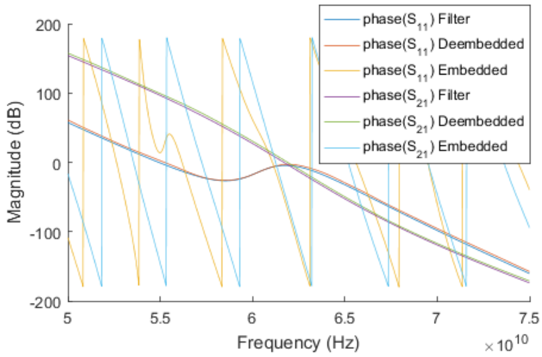

Fig. 6. DUT phase.

References

[1] J. Yang, S. M. Moghaddam, A. Zaman, Z. S. He, V. Vassilev, “PCB Based UWB mm-Wave Smart Capped Bowtie Array for 5G Communication Systems,” *2018 IEEE international Symp. on Antennas Propag (APS)*, Boston, July 2018

[2] U. Nandi, A. U. Zaman, A. Vosoogh and J. Yang, ”Millimeter wave contactless microstrip-gapwaveguide transition suitable for integration of RF MMIC with gap waveguide array antenna,” *2017 11th European Conference on Antennas and Propagation (EUCAP)*, Paris, 2017, pp. 1682-1684

[3] Glenn F. Engen, Cletus A. Hoer, ‘‘Thru-Reflect-Line: An improved technique for calibrating the dual six port automatic network analyzer’’, *IEEE Transactions on MTT,* vol.27, no.12, pp. 987-993, December 1979

[4] Ashraf Zaman, Uttam Nandi , Jian Yang, “A packaging structure comprising at least one transition forming a contactless interface”, Patent Application PCT/SE2016/050949, 05 October 2016.