Simplified De-embedding for Return Loss Estimation

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***Abstract*—In some applications, it is shown that the peak return loss of a Device Under Test (DUT) can be accurately estimated from a knowledge of the magnitude of the s-parameters of the test fixture and the assembly. Numerical results illustrate advantages and limitations.**

I. INTRODUCTION

The work presented in this paper addresses two important Signal Integrity applications. First, s-parameter measurements of a DUT (denoted by D) invariably involve a Test fixture (denoted by F). De-embedding requires the s-parameters of the test fixture, and an s-parameter simulator. In a second application, it is desirable to know the return loss of a link comprising several parts which again requires an s-parameter simulator. During a channel system architecture phase, quick estimates are needed. These are easy to do with insertion loss, but not with return loss, and this work presents a simple approximation useful in both cases.

II. THEORY

Consider an example shown in Fig.1. Using the chain-matrix conversion, the s-parameter matrix of the cascaded network (denoted by T) can be written as a function of the s-parameters of the D and F as

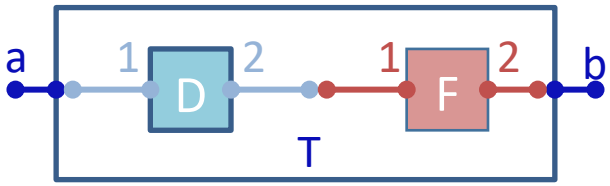

Fig. 1. Illustration of two 2-port networks in cascade

$$\begin{bmatrix} S_{aaT} & S_{abT} \\ S_{baT} & S_{bbT} \end{bmatrix} = \begin{bmatrix} S_{11D} - S_{11F}S_{12D}S_{21D}/\Delta & -S_{12D}S_{12F}/\Delta \\ -S_{21D}S_{21F}/\Delta & S_{22F} - S_{22D}S_{12F}S_{21F}/\Delta \end{bmatrix} \quad (1)$$

Where $\Delta = (S_{11F}S_{22D} - 1)$

For a reciprocal system comprising an electrically short DUT and an electrically long test fixture, the return loss of a DUT can be approximated by a simple equation as

$$|S_{22D}| \approx \big||S_{bbT}| - |S_{22F}|\big|/|S_{12F}|^2 \quad (2)$$

This situation arises in the measurement of s-parameters of IC packages using multi-line coaxial connectors on the BGA side and micro-probes on the die side.

III. NUMERICAL RESULTS AND CONCLUSION

For illustration, an example is chosen where D consists of a package interconnect geometry including the BGA (Ball Grid Array), and a short trace on a PCB to which a multi-line connector (F) is attached. Characteristics of D are simulated and those of F are obtained by measurement as shown in Fig.1.

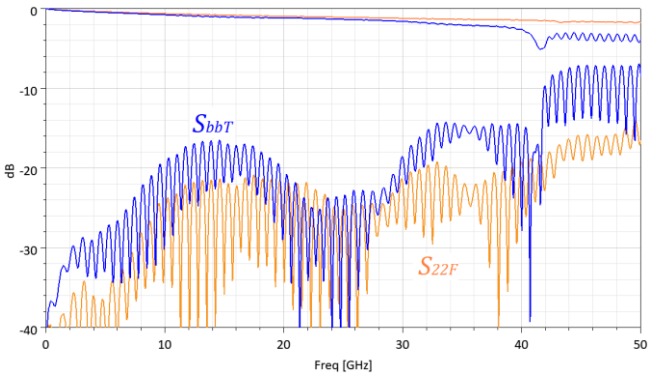

Fig. 2. Measured s-parameters of F and computed s-parameters of T

An application of Eqn. 2 shows that peak values of the estimate are very close to actual values (Fig. 2). These can be easily calculated from a knowledge of the magnitudes of the s-parameters of F and T. However, a link budget estimation of return loss using Eqn. 2 can sometimes be pessimistic in which case it will be necessary to use Eqn.1.

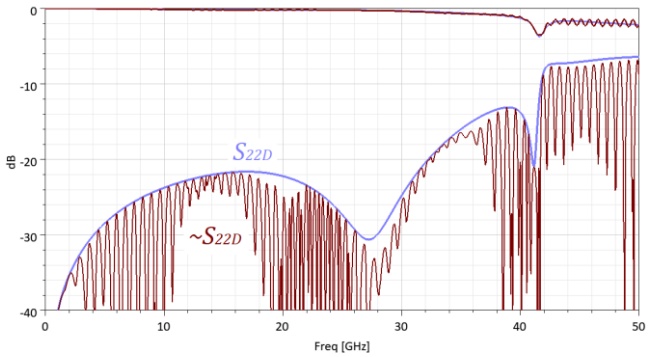

Fig. 3 Actual s-parameters of D and approximated values from Eqn. 2

Take-Home Messages:

- Provide simple equations for return loss estimation.
- Useful in de-embedding package measurements
- Useful in Channel Link budget estimation

REFERENCES

[1] IEEE 370-2020, IEEE Standard for Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50GHz, 2020.