

Probing and Fixturing Techniques for Wideband Multiport Measurements in Digital Packaging

Dem Promotionsausschuss der
Technischen Universität Hamburg-Harburg
zur Erlangung des akademischen Grades
Doktor-Ingenieur (Dr.-Ing.)
vorgelegte Dissertation

von

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aus

Dimitrovgrad, Bulgarien

2013

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Tag der mündlichen Prüfung: 1.02.2013

Berichte aus der Elektronik

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**Probing and Fixturing Techniques for Wideband
Multiport Measurements in Digital Packaging**

Shaker Verlag
Aachen 2013

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Zugl.: Hamburg-Harburg, Techn. Univ., Diss., 2013

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Printed in Germany.

ISBN 978-3-8440-1910-0

ISSN 1436-3801

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen

Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9

Internet: www.shaker.de • e-mail: info@shaker.de

Abstract

This thesis deals with test signal probing and fixturing techniques for wideband multiport measurements in digital packaging in the frequency range from a few MHz to 50 GHz. Three different signal launch techniques are investigated in time and frequency domains. At first, the performance of the coaxial surface mounted connector launch is explored in case of crosstalk measurements in a backplane connector via pin field. In the next step the recessed probe launch technique is briefly presented. After that the main focus is on the results obtained in recent investigations with respect to the launch calibration, application to measurements of embedded multilayer structures and modifications to improve the launch bandwidth. Finally, the concept of a novel multiport probing fixture is presented and its electrical performance explored. Using a simple two-tier calibration procedure, the effect of the probing fixture on measurements of dense via array structures is reduced and the results obtained are validated with microprobe based measurements. Based on 3D full-wave electromagnetic modeling, suggestions for layout optimization are made which will be needed to extend the applicability of these techniques to data rates of 20 Gbit/s and beyond.

Kurzfassung

Diese Arbeit befasst sich mit der Testsignalkontaktierung und Signaleinführungstechniken für breitbandige Multitor-Messungen im Bereich der Aufbau- und Verbindungstechnik für digitale Systeme im Frequenzbereich von wenigen MHz bis 50 GHz. Drei verschiedene Signaleinführungstechniken werden im Zeit- und Frequenzbereich untersucht. Zuerst wird die Leistungsfähigkeit der Kontaktierung mit koaxialen Steckern in Messungen des Übersprechens von Backplane-Stecker analysiert. Im nächsten Schritt wird die "Recessed Probe Launch"-Technik präsentiert, wobei die Ergebnisse aus aktuellen Untersuchungen in Bezug auf ihre Kalibration, ihre Anwendungen für Messungen von eingebetteten Multilagen-Strukturen und mögliche Modifizierungen für die Verbesserung der Messbandbreite im Mittelpunkt stehen. Schließlich wird das Konzept eines neuartigen Multitor-Adapters präsentiert und seine Hochfrequenz-Eigenschaften untersucht. Mittels eines zweistufigen Kalibrationsverfahrens wird der Einfluss des Multitor-Adapters in den Messungen von dichten Via Array Strukturen reduziert und die Ergebnisse mit Microprobe-Messspitzen basierten Messungen validiert. Basierend auf 3D Vollwellen-Simulationen werden Vorschläge für die Optimierung des Layouts gemacht, die für die Anwendbarkeit dieser Technik für Datenraten bis 20 Gbit/s und darüber hinaus notwendig sind.

Acknowledgment

In the first place, I would like to express my gratitude to Prof. Dr. Christian Schuster, for giving me the opportunity for carrying out this work, and for the dedicated guidance and advice during my research work at the Institute of Electromagnetic Theory (TET) of the Technical University of Hamburg-Harburg (TUHH). His honesty, directness, humanity, and commitment to the research and academic activities have always motivated me during all this time.

I would also like to thank Prof. Arne Jacob for being the co-examiner and for the careful review of this work.

My gratitude goes to Dr. Young H. Kwark, who was also external examiner of this work. His support and feedback along the different phases of this project have been essential for its successful completion. I would like to thank to Dr. Xiaoxiong (Kevin) Gu and M. S. Christian Baks, and the other members of the former High-Speed I/O Subsystems and Packaging Group at the IBM T. J. Watson Research Center, Yorktown Heights, New York, USA, who have cooperated a lot with our research and bore the costs for manufacturing of the test hardware used in this work.

I would like to express my gratitude to all the colleagues and staff at the Institute of Electromagnetic Theory for their support. It has been a great experience working with them. I am grateful to Dr. Heinz Brüns for numerous discussions and suggestions to the academic and research activities. I also thank Heike Herder, Dipl.-Ing. Angela Freiberg, Stefan Conradi, and Walter Burmester for the administrative and technical supports. Special thanks to my colleagues Dr.-Ing. Xiaomin Duan, Dr.-Ing. Renato Rimolo-Donadio, Dipl.-Ing. Sebastian Müller, Dipl.-Ing. Andreas Hardock, Dipl.-Ing. Arne Schröder, M.Sc. Alexander Vogt for their help and great team work. I also appreciate Prof. Frank Gronwald, Dr. Miguel Astner, Dr. Volker Vahrenholt, for various supports and productive discussions.

Finally, I would like to thank to my family and friends. Special thanks to my schoolmate Dipl.-Kfm. Stefan Tschorbadshiew for our regular discussions and his mental support during my research activities and the writing of this work.

I would like to thank to Dr. Gerhard Stelzer for his support, numerous discussions, and the experience from our collaboration during my study at TU Kaiserslautern, which were path breaking and have motivated me during my work at TUHH.

I am grateful to my sister Elena, Minko and Monika for their termless support and responsiveness. I am thankful to my parents Gospodinka and Anastas for giving me the opportunity to study in Germany and for their support throughout my university education. This thesis is for them.

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List of Symbols and Acronyms

Notation

x, y, z Cartesian coordinates

Symbols

V_0	Amplitude of the inserted step voltage
V_r	Amplitude of the obtained reflected voltage
ω	Angular frequency
α	Attenuation constant
T_b	Bit time
F_{-3dB}	Bandwidth of the low-pass filter of a time domain oscilloscope
C	Capacitance
Z_0	Characteristic impedance
σ	Conductivity
I	Current
$\tan\delta$	Dielectric loss tangent
$\Delta\varphi_{eff}$	Effective phase difference
f	Frequency
$f_{\lambda/4}$	Frequency at a quarter-wavelength
F_{notch}	Frequency where a deep notch appears in the transmission parameters
I	Identity matrix
j	Imaginary unit
L	Inductance

f_{max}	Maximum frequency of interest
T_{signal}	Period
μ_0	Permeability of free space ($\sim 4\pi \cdot 10^{-7}$ H/m)
ϵ_0	Permittivity of free space ($\sim 8.854 \cdot 10^{-12}$ F/m)
β	Phase constant
γ	Propagation constant
T_{single}	Propagation time of a single discontinuity
μ_r	Relative permeability
ϵ_r	Relative permittivity
R	Resistance
t_r	Rise time
T_{meas}	Rise time delivered at the end of a probe or a fixture
T_{TDR}	Rise time in accordance with the TDR module data sheet
S	S-parameter
t	Time
Δl	Trace length mismatch
T	Transformation matrix for currents (modal decomposition)
l	Transmission line/ trace length
λ	Wavelength
Y	Y-parameter
Z	Z-parameter

Acronyms

2D	Two Dimensional
3D	Three Dimensional
ABCD	Microwave Network Chain Parameters
AC	Alternating Current
ATE	Automatic Test Equipment
BGA	Ball Grid Array

CM	Common-Mode
CPW	Coplanar Waveguide
CS	Calibration Substrate
DC	Direct Current
DDR	Dual Data Rate (for random access memories)
DR	Data Rate
DUT	Device Under Test
ECAL	Electronic Calibration Module
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FEM	Finite Element Method
FEXT	Far-end Crosstalk
FFT	Fast Fourier Transform
FIT	Finite Integration Method
GND	Ground
GS	Ground Signal
GSG	Ground Signal Ground
HDMI	High Definition Multimedia Interface
HFSS	High Frequency Structure Simulator (FEM Solver)
IBM	International Business Corporation
IC	Integrated Circuit (or chip)
IEEE	Institute of Electrical and Electronics Engineers
LGA	Land Grid Array
LRM	Line-Reflect-Match (Calibration Procedure)
LRRM	Line-Reflect-Reflect-Match (Calibration Procedure)
MMSNT	Microwave Measurement Software
NEXT	Near-end Crosstalk
PCB	Printed Circuit Board
PI	Power Integrity
PLTS	Physical Layer Test System
PTFE	Polytetrafluorethylen

QSOLT	Quick-Short-Open-Load-Thru (Calibration Procedure)
RF	Radio Frequency
RPL	Recessed Probe Launch
RPM	Revolutions Per Minute
S-	Microwave Network Scattering Parameters
SATA	Serial Advanced Technology Attachment
SG	Signal Ground
SI	Signal Integrity
SMA	SubMiniature version A
SMP	SubMiniature Push-On
SMT	Surface Mount Technology
SOL	Short-Open-Load (Calibration Procedure)
SOLR	Short-Open-Load-Reciprocal (Calibration Procedure)
SOLT	Short-Open-Load-Thru (Calibration Procedure)
SWR	Standing Wave Ratio
TDR	Time Domain Reflection
TDT	Time Domain Transmission
TEM	Transverse ElectroMagnetic
TET	Institut für Theoretische Elektrotechnik, TUHH
TL	Transmission Line
TRL	Thru-Reflect-Line
TUHH	Technische Universität Hamburg-Harburg
TV	Test Vehicle
VNA	Vector Network Analyzer

In this work board and structure dimensions are often given in mils, which are the typical units used in the electronic industry. The conversions to SI units are as follows:

$$1 \text{ inch} \approx 2.54 \cdot 10^{-2} \text{ m}$$

$$1 \text{ mil} = 0.001 \text{ inch} \approx 25.4 \cdot 10^{-6} \text{ m}$$