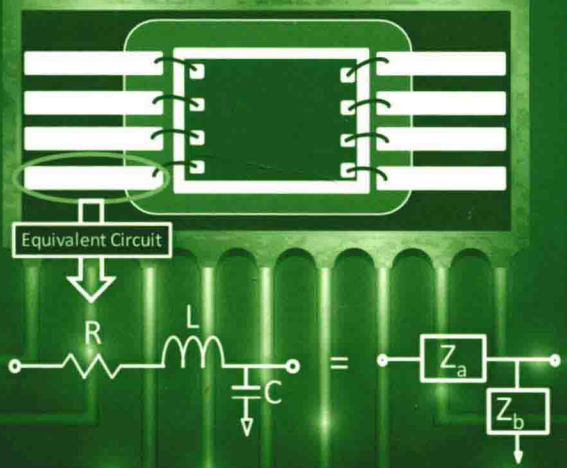
Microwave and Millimeter-Wave Electronic Packaging



Rick Sturdivant

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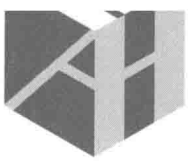

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turn to the back of this book.

This work is dedicated to my wife, Jonie,
and my parents, Jim and Linda

Preface

Packaging of electronic components at microwave and millimeter-wave frequencies requires the same level of engineering effort used for lower frequency electronics, plus a set of additional activities that are unique due to the higher frequency of operation. Without careful attention to these additional issues, it is not possible to successfully engineer electronic packaging at these frequencies. This book presents the electronic packaging issues that are unique to microwave and millimeter-wave frequencies and reviews general electronic packaging techniques for how they can be tailored to higher frequency designs.

The book chapters are organized into groups. Each chapter has a few examples, some of which are mentioned here. Two free software analysis programs are also provided and discussed in the examples. The software programs are available for downloading from www.ricksturdivant.com.

Chapter 1 begins with an introduction to the topic of packaging at microwave and millimeter-wave frequencies. Why is packaging at these frequencies so difficult? The answer to this question as well some concrete examples are given. This chapter concludes with an introduction to the concept of first-level, second-level and circuit board-level packaging.

Chapters 2, 3, and 4 address materials issues, ceramic packaging, and laminate circuit boards. These three topics are grouped together because they form the material foundation for most electronic packaging. Although the topic of materials could warrant its own volume, Chapter 2 addresses materials issues that are of particular interest for high-frequency package designs. In particular, the impacts of material choices on electrical and thermal performance are shown. Chapter 3 focuses on ceramics for packaging. It starts with a brief history of the development of ceramics and moves to thin films, thick films, and HTCC and LTCC packaging. Although ceramics are very common at these

frequencies, laminate-based packaging, which is the topic of Chapter 4, is very attractive for low-cost, high-volume products.

Chapters 5 and 6 focus on first- and second-level packaging challenges. First-level packaging includes wire bonds, ribbon bonds, and flip chips. Chapter 5 focuses on the electrical modeling of wire bonds and flip chip interconnects. Equivalent circuits are developed and modeling methods are discussed. Second-level packaging, discussed in Chapter 6, includes quad flat no-lead (QFN) packages, leadless chip carriers, and packages with leads and solder bump packages. Of particular concern is the proper modeling of package-to-motherboard transitions so several modeling methods are shown to address this.

Chapters 7 and 8 deal with modules, motherboards, transitions, and 3D packaging. Microelectronic modules and motherboards, discussed in Chapter 7, must have properly designed transmission lines to interconnect between integrated circuits, which is the main focus of the chapter. Practical design issues such as avoiding higher order modes and coupling are discussed. The chapter concludes with discussions on the use of isolation vias and avoiding cavity resonances. The focus of Chapter 8 is on transitions between signal transport structures such as transmission lines and 3D packaging interconnects. Transitions between CBCPW, microstrip, and a vertical transition between stripline and microstrip are shown. Considerable emphasis is placed on the development of a model based on closed-form equations for the microstrip-to-stripline transition. Many products are moving to 3D packaging to achieve the levels of integration required and, hence, require the use of compressible connectors for module and circuit board stacking.

Chapters 9 and 10 focus on thermal/heat transfer and electromagnetic modeling of packages. Chapter 9 starts with a review of heat transfer mechanisms, then provides details on high-power amplifier thermal modeling with the goal of maintaining device junction temperatures to ensure reliability. The chapter concludes with a discussion of thermal modeling methods and approximation techniques. Chapter 10 addresses electrical design from the perspective of using electromagnetic design tools that have been commercialized during the past 20 years. The chapter is a high-level overview of electromagnetic analysis for electronic packaging.

The book concludes with Chapter 11. The preceding chapters are tied together with a discussion of the 10 keys to successful packaging at microwave and millimeter-wave frequencies. The chapter then concludes with discussion about some of the new horizons in electronic packaging including chip scale packaging, MEMS etching techniques, and new 3D material fabrication techniques.

In the text, *radio-frequency* is abbreviated as rf and is used in the most general sense to describe electromagnetic waves up through millimeter-wave frequencies. The word *high frequency* is used in the same sense. Throughout

most of the book, dimensions are given in units of meters except in the rare case where industry standards require the use of other units.

Electromagnetic simulations were conducted using High Frequency Structure Simulator (HFSS) from ANSYS, Inc. The author would like to thank Mr. Edmond Megerdichian for developing some of the 3D images used in the figures. The author would also like to thank the various companies that graciously supplied the images and photographs that improve the practical usefulness of this work. Samantha Ronan, the developmental editor at Artech House, was very helpful, and the reviewers of the manuscript deserve special thanks for improving my initial drafts. Finally, I would like to thank all of the wonderfully talented engineers who I have had the privilege of working with and learning from throughout my career. This is especially true of the team at the Solid State Microwave Lab at Hughes Aircraft Company.

Contents