Preface

For the purpose of identifying the large-signal behavior of the transistor devices, the use of linear S-parameter is often inadequate. Large-signal characterization, therefore, is essential for the estimation and determination of the device performance in the nonlinear domain. The load-pull approach is one recommended approach for the large-signal characterization, optimization, and design of transistor devices and radio frequency (RF), microwave and mm-wave power amplifiers (PAs).

The load-pull technique was first reported almost four decades ago. This pioneering work brought a paradigm shift in the characterization, measurement, and optimization of transistor devices and PAs. The first load-pull setup can be considered rudimentary but has definitely helped in advancing the state-of-the-art in load-pull techniques.

This book describes the principles of operation, calibration, design and realization approaches and application of load-pull techniques in the context of PAs. It explores the topic from the basic principles of load-pull techniques through to their many interesting advancements, including passive and active techniques, high power load-pull and envelope load-pull setups with applications to amplifier, mixer and noise measurements. In addition, the book also covers waveform engineering systems, their calibration techniques and applications.

The book can be used by graduate students, researchers and design engineers in microwave and wireless design areas. It is assumed that the readers have already acquired a basic knowledge of RF and microwave circuit design. A solid background in transmission line theory and basic communication concepts is required. The book may also be used as a textbook for a graduate course on large signal device measurement and characterization.

Chapter 1 is a brief reminder of the basic concepts related to PA characteristics, figures of merits of PA, power amplifier classes of operation, PA design methodologies, and introduction to load-pull systems along with their important features.

Chapter 2 is dedicated to passive load-pull techniques. It explains the fundamentals of passive load tuning techniques and elaborates on the two most common techniques, namely electronic tuner (ETS) and electromechanical tuner (EMT), employed to achieve impedance tuning using passing approach. Measurement and calibration procedure applied in a load-pull measurement setup is then discussed in detail. The chapter also provides extensive details on various passive harmonic load-pull architectures along with their respective advantages and limitations. Subsequently, common techniques used to enhance the tuning range of passive load-pull setups are discussed.

Chapter 3 provides extensive details on active load-pull techniques and systems. It starts with closed-loop active load-pull technique and its realization methods. Adequate details have been included for the design of application specific closed-loop load-pull system. It then covers feed-forward active load-pull and various methods to develop hybrid setup, for enhancing the tuning range and achieving highly reflective load-pull systems. Active open-loop load-pull requires iterative operation of the system for converging on optimal impedance solution. The last section is dedicated to an algorithm for high speed convergence in active open-loop load-pull systems.

Chapter 4 presents the theory, techniques and principles behind using six-port reflectometer in reverse and forward configurations to characterize transistors operated in large signal conditions, and the issues related to the implementation of these techniques are discussed. Source-pull characterization using six-port reflectometer for transistor noise measurement, mixer testing and design, as well as oscillator device line measurement purposes are explained and discussed. AM/AM and AM/PM distortion measurement and passive and active load-pull large signal characterization of transistors using the six-port reflectometer technique are also presented and discussed.

Chapter 5 deals with the issues involved in the characterization of high power microwave transistor devices. There are multiple aspects that need to be addressed in order to overcome those issues. All these have been discussed in detail in this chapter. The techniques adopted in customizing the load-pull setup for high power device measurements and characterization applications have been elaborated and explained in detail. Finally, emerging solutions catering to large periphery high power microwave devices are presented.

Chapter 6 presents the theory of active envelope load pull (ELP) and the associated design and calibration techniques of active envelope load-pull. Thereafter harmonic envelope load-pull is explained in detail which is followed by some unique measurement applications of envelope load-pull system.

Chapter 7 is dedicated to theory and calibration approaches adopted in developing error corrected nonlinear time-domain waveform measurements systems. Subsequently the concept of waveform engineering is presented. Finally, a number of applications of waveform engineering system are discussed.

Chapter 8 presents some advanced applications and configurations of load-pull setups. The first part of this chapter primarily discusses the concept of load-pull systems for multi-tone and modulated excitations. It experimentally demonstrates that such systems are extremely useful for real life practical applications. Then the use of load-pull and source-pull systems in noise characterization is described in detail. Finally application of load-pull systems in mixer characterization and measurements in presented.