**WFE (IMS) Friday 08:00 – 12:00 BCEC Room 156A**
**Stability of Nonlinear Microwave Circuits and Systems: Concepts, Analysis, and Design**
**Half-day workshop reviewed by MTT-16, MTT-1, MTT-6**

**Organizer(s):**
Christopher P. Silva, The Aerospace Corporation; MTT-16.
Almudena Suárez, University of Cantabria; IMS TPC.

This workshop provides a comprehensive and practical treatment of the general nonlinear stability problem that arises in essentially all modern microwave circuits and systems. It is motivated by the fact that current analysis and design practices are inadequate at mapping out the full behavior of a given circuit or system, thereby leading to the possibilities of anomalous unstable behaviors or designs with marginal stability. There are several important instances, ranging from commercial to military arenas, in which this inadequacy has resulted in costly consequences and delays. As performance demands increase, this problem will become more commonplace as implementation complexity increases and design margins decrease. The workshop will address the three basic aspects of this subject: concepts, analysis, and design applications. The treatment here will be fundamentally based on the dynamical system paradigm and will address local, global, and input/output stability. An introduction to the dynamical system framework will first be provided, including a detailed definition and classification of the steady-state behavior of these systems and their stability (linear and nonlinear) that will encompass and generalize current stability criteria commonly used in practice (e.g., stability factors). The concept of bifurcation, or stability change, will be introduced, together with a survey of the wide variety of forms (and routes) that this phenomenon can manifest itself. The next portion of the workshop will address the important detection and analysis of bifurcations in microwave circuits and systems, including two fundamental approaches that have been implemented either as a modification to currently available CAD platforms (e.g., Agilent ADS), or as stand-alone specialized software packages. The important technique of bifurcation control will also be described that allows for the development of robustly stable designs. With these tools in place, a representative and relevant set of applications will be covered, including such common circuits and systems as oscillators, power amplifiers, frequency dividers, self-oscillating mixers, frequency multipliers and phase-locked loops. In addition, special attention will be paid to parametric circuits, as they can still be advantageously used to implement several important nonlinear functions. Their operation principle, based on the periodic variation of a nonlinear reactance, helps in the understanding of common parametric instabilities found in nonlinear microwave circuits. The serious and still unresolved problem of instabilities in multi-device circuits, such as multi-function MMIC chips, will also be addressed, presenting available techniques to locate the instabilities in large, complex-topology circuits. Attendants of this workshop should come away with a new area of knowledge and tool set that will allow them to completely analyze the stability of their current designs, and make future ones more robustly stable in their behavior.

**Speakers:**

1. Christopher P. Silva, The Aerospace Corporation, USA
"Overview of Steady-State Stability Concepts and Analysis for Microwave Circuits & Systems"

This presentation provides theoretical foundations and framework for the basic stability and bifurcation concepts addressed in this workshop, and an overview introduction to the entire workshop. Practical implementation and application details will be subsequently supplied by other workshop speakers. The talk first introduces the dynamical systems perspective and its basic concepts. Descriptive definitions of stability, ranging from local to global, come next, followed by a survey of the bifurcations of equilibria, fixed points and beyond. A brief review/evaluation of traditional stability analysis approaches is then given, followed by two examples motivating the workshop. The presentation ends with brief highlights of basic CAD-implemented approaches for detecting/ computing stability routes, the bifurcation control design method that increases stability margins, and a representative listing of microwave circuits and systems for which these techniques can be fruitfully applied.

2. Almudena Suárez, University of Cantabria, Spain
"Bifurcation Analysis and Control in Nonlinear Microwave Circuits"

A bifurcation is a qualitative change in the stability of a solution or in the number of solutions when a parameter (such as the input power or bias voltage) varies continuously. This gives rise to an abrupt change in the solution observed. Examples are the onset of an oscillation, the hysteresis or the division by two of the fundamental frequency. The purpose of the talk is to describe in detail the most common types of bifurcations in nonlinear microwave circuits such as power amplifiers, frequency dividers and free-running oscillators. The bifurcations delimit the stable operation ranges of these circuits, so they have a crucial influence on their performance. Operation near a bifurcation can also give rise to noise amplification, which degrades the output power spectrum. The talk will introduce the main types of bifurcations, with practical examples. It will provide simple-application techniques to analyze and suppress these bifurcations or modify their properties.

3. Juan Mari Collantes, University of the Basque Country, Spain
"Expanding the Capabilities of Pole-Zero Identification Techniques for Stability Analysis"

Pole-zero identification techniques are being increasingly used for stability analysis of microwave circuits, both in small- and large-signal regimes. In its basic form, this technique is used just to verify whether a circuit will oscillate or not. In this presentation the possibilities provided by pole-zero identification results are extended in order to improve their effectiveness. For that, combined analysis with voltage and current probes are proposed as a way to improve the sensitivity in the pole-zero identification. All the topics are discussed and illustrated through their application to practical examples of stability analysis of power amplifiers.

4. Diego Masotti, University of Bologna, Italy
“Global Stability Analysis of Nonlinear Microwave Circuits Based on Numerical Implementation of Bifurcation Theory ”

The presentation reviews the fundamentals of the bifurcation-based approach to the global stability analysis of nonlinear microwave circuits. The numerical implementation of Nyquist’s analysis is first addressed, and the differences between forced and autonomous circuits are examined in depth. The numerically efficient construction of solution paths in the state space of a parametrized circuit is then considered, and an automatic switching-parameter algorithm for automatically overcoming the turning points is introduced. The automatic development of a global stability pattern for the circuit under consideration is demonstrated, and the relationships between stability and noise are highlighted. Several practical examples of application are provided, including the spurious-free design of oscillators, the stability analysis of MEMS switching circuits under large-signal drive, and the determination of the complex stability patterns of MEMS-reconfigurable microstrip antennas.

5. Sebastien Mons, University of Limoges — CNRS, France
“Stability Issues in the Design of High Power Amplifiers and Oscillators”

Checking the linear and nonlinear stability of power amplifiers or oscillators before their fabrication is mandatory for RF engineers. Methods based on Large Signal Small Signal have been proposed since some years now. They proved efficient in the quasi static regime and are now widely used. Moreover some characterizations methods have been investigated that allow to measure the frequency conversion characteristics of active devices or circuits. The proposed talk will give a review of state of the art techniques for assessing stability of nonlinear devices from theoretical and practical points of view

6. Robert Melville, USAP, McMurdo Station, USA
“Theory and Applications of Strong Parametric Excitation”

We will describe various circuits for "parametric oscillators", based on varactor diodes. The design, simulation, prototyping and applications of such circuits will be discussed.