Preface

This book on microwave RF circuits: nonlinearity applications in engineering covers and deals with two separate engineering and scientific areas and what between. It gives advance analysis methods for Microwave RF Circuits which represent many applications in engineering. Microwave RF Circuits come in many topological structures and represent many specific implementations which stand the target engineering features. Microwave RF Circuits include RFID antenna systems, microwave elements, microwave semiconductor amplifiers, small-signal (SS) amplifiers and matching networks, power amplifiers, oscillators, filters, antennae systems, and high-power transistor circuit. The basic Microwave RF Circuits can be characterized by some models and the associated equations. The Microwave RF Circuits include RFID ICs and antennas, microstrip, circulators, cylindrical RF network antennas, tunnel diode (TD), bipolar transistors, field-effect transistors, IMPATT amplifiers, small-signal (SS) amplifiers, Bias-T circuits, PIN diode, power amplifiers, LNAs, oscillators, resonators, filters, N-turn antennae, dual spiral coils antennae, Helix antennas, linear dipole and slot array, and hybrid translinear circuit. The Microwave RF Circuits analyze as linear and nonlinear dynamical systems and their dynamics under parameter variations. This book is aimed at newcomers to linear and nonlinear dynamics and chaos Microwave RF Circuits. The presentation stresses analytical and numerical methods, concrete examples, and geometric intuition. The Microwave RF Circuits analysis is developed systematically, starting with first-order differential equations and their bifurcation, followed by phase plane analysis, limit cycles and their bifurcations, chaos, iterated maps, period doubling, renormalization, and strange attractors. Additionally, the book is dealt with delayed Microwave RF Circuits which characterized by overall variables delayed with time. Each variable has specific delay parameter and can be inspected for dynamics. More realistic Microwave RF Circuits models should include some of the past states of Microwave RF Circuits and systems; that is, ideally, a real Microwave RF Circuits should be modeled by differential equations with time delays. The use of delay differential equations (DDEs) in the modeling of Microwave RF Circuits dynamics is currently very active, largely due to progress achieved in the understanding of the dynamics of
several classes of delayed differential equations and Microwave RF Circuits and systems. This book is designed for advanced undergraduate or graduate students in electronics, RF and electronic engineering, physics, and mathematics who are interested in Microwave RF Circuits dynamics and innovative analysis methods. It is also addressed to electrical and RF engineers, physics experts and researchers in physics, electronics, engineering and mathematics who use dynamical systems as modeling tools in their studies. Therefore, only a moderate mathematical and electronic semiconductor background in geometry, linear algebra, analysis, and differential equations is required. Each chapter includes various Microwave RF Circuits drawing and their equivalent analyses circuits. Microwave RF Circuits fixed points and stability analysis done by using much estimation. Various bifurcations of Microwave RF Circuits are discussed.

In this book, we try to provide the reader with explicit procedures for application of general Microwave RF Circuits mathematical representations to particular research problems. Special attention is given to numerical implementation of the developed techniques.

Let us briefly characterize the content of each chapter.

Chapter 1. RFID Antenna Systems Descriptions and Analysis. In this chapter, RFID antenna systems are described and analyzed. RFID is a dedicated short-range communication (DCRC) technology. RFID system consists of an antenna and a transceiver, which read the radio frequency, and transfers the information to a processing device (reader) and a transponder, or RFID tag. Active RFID tag system includes energy source (battery), and it consumes energy. The active RFID tag system is analyzed as an excitable linear bifurcation system. RFID tag-dimensional parameters are optimized to get the best performances. Under delayed electromagnetic interferences, there are delays in some RFID tag coil variables and we analyze it for stability optimization. There is a unique structure of RFID system, semi-passive RFID tags with double-loop antennae arranged as a shifted gate. The structure is optimized under delayed electromagnetic interferences. RFID tag detector circuit is implemented by using schottky diode, and stability is analyzed for parameter values variation. RFID system burst switch is a very important element, and its behavior in time is inspected. The analysis fills the gap of analytical methods for RFID systems analysis, concrete examples, and geometric examples. One of the crucial RFID system optimization is in electromagnetic environmental which faced RFID system variables delay in time. In some cases, RFID system can be represented as delayed differential equations, which depends on variable parameters and delays. There are practical guidelines that combine graphical information with analytical work to effectively study the local stability of RFID system models involving delay-dependent parameters.

Chapter 2. Microwave Element Description and Stability Analysis. In this chapter, microwave element stability is discussed. There are three types of microwave circuits which include microwave elements. The first is a discrete circuit, packaged diodes/transistors mounted in coax and waveguide assemblies. The second is Hybrid MIC (microwave integrated circuit), diodes/transistors and microstrip fabricated separately and then assembled. The third is MMIC
(monolithic microwave integrated circuit), diodes, transistors, and microstrip circuits, and other circuit elements, such as lumped capacitors and resistors, which have parasitic effects influenced on overall system stability behavior. Microwave transmission lines are delayed in time and are integral part of power limiter; the stability is inspected for optimization. Reflection-type phase shifter (RTPS) employs a circulator. The RTPS circuit includes microstrip transmission lines with three-port active circulator and analyzes for stability optimization under time delayed. Cylindrical RF network antennas for coupled plasma sources include copper legs. They run as large-volume plasma sources and have stability switching due to system’s copper leg parasitic effects. Tunnel diode (TD) is the p-n junction device that exhibits negative resistance. Tunnel diode (TD) can be a microwave oscillator. Transient is in the resonant cavity after turning the bias voltage ON. The resonant circuit with NDR can oscillate. The Tunnel diode (TD) microwave oscillator has parasitic effects in time and delay variables. The stability is optimized when implementing tunnel diode (TD) in microwave oscillator.

Chapter 3. Microwave Semiconductor Amplifiers Analysis. In this chapter, microwave semiconductor amplifier circuit analysis is discussed. Microwave semiconductor amplifiers are widely used, and stability analysis is needed. Microwave semiconductors can be bipolar transistors which operate at microwave frequencies, and microwave field-effect transistors (FETs) minimize the adverse effects of transit time and internal capacitance and resistance, IMPATT (impact-ionization avalanche transit time) amplifier which widely used at the high end of the microwave band. Stability of these microwave amplifiers is affected by internal parameter variation and circuit microstrip parasitic effects. IMPATT diodes which are a form of high-power diode are used in high-frequency electronic and microwave devices. FET-combined biasing and matching circuit has many stability issues which must be taken for every RF design, and analysis is done for best performances.

Chapter 4. Small Signal (SS) Amplifiers and Matching Network Stability Analysis. In this chapter, small-signal (SS) amplifiers and matching network structures are analyzed for best performances. There are some types of amplifiers. Amplifiers types are zero-frequency amplifiers (DC amplifiers), low-frequency amplifiers (audio amplifiers), and high-frequency amplifiers (RF amplifiers). Amplifiers come in three basic flavors: common base (CB) amplifiers, common collector (CC) amplifiers, and common emitter (CE) amplifiers. It depends whether the base, collector, or emitter is common to both the input and output of the amplifier. When an amplifier’s output impedance matches the load impedance, maximum power is transferred to the load and all reflections are eliminated. When an amplifier’s output impedance unmatched the load impedance, there are reflections and less than maximum power is transferred to the load. There are instability behaviors in these three types of amplifiers caused by circuit microstrip delays in time parasitic effects. We use RF matching network in our design. There are typical amplifiers matching networks: L matching network, T matching network, and PI matching network. In design of microwave matching network, device parasitic effects of length on RF circuit matching and stability. Bias-T three-port network
also suffers from instability under delayed microstrip in time. A PIN diode is suitable for many applications and operates under high level of injection. The PIN diode suffers from instability under parameter variations.

Chapter 5. **Power Amplifier (PA) System Stability Analysis.** In this chapter, power amplifiers (PAs) are analyzed for best performances, and stability was also discussed. Large-signal or power amplifiers (PAs) are used in the output stages of audio amplifier systems to derive a load speaker. There are different types of amplifiers which classified according to their circuit configurations and method of operation. The classification of amplifiers ranged from linear operation with very low efficiency to nonlinear operation but with a much higher efficiency, while others are a compromise between the two. There are two basic amplifier class groups. The first are the classically controlled conduction angle amplifiers forming the more common amplifier classes (A, B, AB, and C). The second set of amplifiers are the newer so-called switching amplifier classes (D, E, F, G, S, T). The most commonly structured amplifier classes are those that are the most common type of amplifier class mainly due to their simple design. We analyze the stability of these amplifiers by inspecting the equivalent circuit differential equations. BJT transistor is replaced by large-signal model in our analysis. The BJT model is known as the Gummel–Poon model. The Ebers–Moll BJT model is a good large signal. We use nonlinear dynamic in our analysis for amplifiers that feed by inputs/outputs exceed certain limits. LNAs are used in many microwave and RF applications. We analyze the stability of wideband low-noise amplifier (LNA) with negative feedback under circuit’s parameter variation.

Chapter 6. **Microwave/RF Oscillator Systems Stability Analysis.** In this chapter, our oscillator systems are discussed and their stability behavior is analyzed. Oscillators can be classified into two types: relaxation and harmonic oscillators. A microwave oscillator is an active device to generate power and a resonator to control the frequency of the microwave signal. Important issues in oscillators are frequency stability, frequency tuning, and phase noise. A phase-shift oscillator is a linear electronic oscillator circuit that produces a sine wave output. The feedback network “shifts” the phase of the amplifier output by 180° at the oscillation frequency to give positive feedback, total phase shift of 360°. Phase-shift resonator circuit stability analysis is done by considering BJT small-signal (SS) equivalent circuit model. Closed-loop functioning oscillator can be viewed as feedback system. The oscillation is sustained by feeding back a fraction of the output signal, using an amplifier to gain the signal, and then injecting the energy back into the tank. Closed-loop functioning oscillator stability is inspected and analyze. There are types of transistor oscillators which use feedback and lumped inductance and capacitance resonators. There are three types of transistor LC oscillators, Colpitts, Hartley, and Clapp. In the Hartley oscillator, the feedback is supplied by the inductive divider formed by two inductors. We apply the stability criterion of Liapunov to our system. Colpitts oscillator is the same as Hertley oscillator and instead of using a tapped inductance, Colpitts oscillator uses a tapped capacitance. Colpitts oscillator circuit stability analysis is done by criterion of Liapunov.
Chapter 7. Filter Systems Stability Analysis. In this chapter, filter systems in many circuits are inspected for dynamical behavior and stability analysis. The target of analog and RF filtering is to modify the magnitude and phase of signal frequency components. Many analog or radio frequency (RF) circuits perform filtering on the signals passing through them. The analog and RF filter types are defined on the criteria how they modify the magnitude and/or phase of sinusoidal frequency components. Microwave and RF filters pass a range of frequencies and reject other frequencies. A diplexer is a passive device that implements frequency-domain multiplexing. Two ports are multiplexed onto a third port. A diplexer multiplexes two ports onto one port, but more than two parts may be multiplexed. We analyze BPF diplexer circuit stability by using geometric stability switch criteria in delay differential systems. A diplexer filters to pass two bands to separate ports, and stability analysis under parameter variation. The standard local stability analysis about any one of the equilibrium points of dual-band diplexer filter circuit is done. We use crystal in place of LC filter for low-frequency applications. There are lattice crystal filter, half lattice, and cascaded half lattice filters. The standard local stability analysis about any one of the equilibrium point of lattice crystal filter circuit is done. A tunable BPF employing varactor diodes is ideal for many diverse wireless applications. There are two types of tunable BPF employing varactor diodes: top inductively coupled variable BPF and capacitively coupled variable band-pass filter. BPF (varactor diodes) circuit involving N variables and stability behavior is inspected.

Chapter 8. Antenna System Stability Analysis. In this chapter, we discussed various antenna systems and behaviors for different conditions for best performances. An antenna is a conductor or group of conductors used for radiating electromagnetic energy into space or collecting electromagnetic energy from space. There are many types of antennas and we discussed those antennas that operate at microwave frequencies. Microwave refer to radio waves with wavelength ranging from as long as one meter to as short as one millimeter with frequencies between 300 MHz and 300 GHz. Another antenna area is for RFID applications. A complete RFID system includes RFID reader and transponder units. N-turn multilayer circular-coil antennas can be integrated with RFID IC for complete RFID tags. We investigate the system stability optimization under delayed electromagnetic interference and parasitic effects. The system is constructed from two antennas: each one N-turn multilayer circular antenna. The standard local stability analysis about any one of the equilibrium points (fixed points) of N-turn multilayer circular-coil antenna RFID system is done. We analyze circuit stability where there is a delay in the first and second RFIDs’ N-turn multilayer-coil antenna voltages and antenna voltage derivatives. A double-rectangular spiral antenna is constructed from two antennas, each antenna is a rectangular spiral antenna. Antennas are connected in series with microstrip line and to the RFID IC. The standard local stability analysis about any one of the equilibrium points of RFID tags with double rectangular spiral antenna system is done. A system of single-turn square planar straight thin-film inductor antenna (four segments) is constructed from four straight thin-film inductors which are connected in a single-turn square structure. There are
delays in time for the microstrip line parasitic effects, and stability switching is inspected for different values of delay variables. A helical antenna is an antenna consisting of a conducting wire wound in the form of a helix. The helical antennas are mounted over a ground plane. Helical antennas can operate in one of two principal modes: normal mode or axial mode. Helix antenna system stability is inspected under parameter variation.

Chapter 9. Microwave RF Antennas and Circuits Bifurcation Behavior, Investigation, Comparison and Conclusion. In this chapter, we summarized the main topics regarding microwave and RF antennas and systems, inspect behavior, dynamics, stability, comparison, and conclusion. Microwave RF antennas are an integral part of every RF or microwave system. An antenna is an electrical device which converts electric power into radio waves, and vice versa. In many wireless applications, antennas are required by radio receiver or transmitter to couple its electrical connection to the electromagnetic field. When we inspect system stability which includes radio waves, we inspect electromagnetic waves which carry signals through the space (or air) at the speed of light with almost no transmission loss. There are mainly two categories of antennas. The first is omnidirectional antenna which receives and/or radiates in all directions. The second is directional antenna which radiates in a particular direction or pattern. Antennas are characterized by a number of parameters, radiation pattern, and the resulting gain. Antenna’s gain is dependent on its power in the horizontal directions, and antenna’s power gain takes into account the antenna’s efficiency (figure of merit). The physical size of an antenna is a practical issue, particularly at lower frequencies. Stability analysis includes a complete RF system with antennas and matching networks.

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