Analysis and Design of Autonomous Microwave Circuits

ALMUDENA SUÁREZ

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To my father Gerardo Suárez
and my mother Carmen Rodriguez

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Preface

Autonomous circuits are capable of sustaining a steady-state oscillation at a frequency different from those delivered by input generators or their harmonic frequencies. The most obvious example is the free-running oscillator, generating a periodic solution from the energy delivered by direct-current (dc) sources only. Another example is the frequency divider, giving rise to a subharmonic frequency of the input periodic source. In injection-locked regimes, the oscillation frequency agrees with a multiple or submultiple of the input frequency, and this relationship is maintained within certain input frequency and input power intervals. Free-running oscillators and frequency dividers are used primarily in the frequency generation and frequency conversion stages of communication systems. Other applications of injection-locked oscillators take advantage of their high phase sensitivity with respect to their bias sources and component values to obtain phase shifters and phase-shift-keying modulators. In turn, the coupled-oscillator systems are composed of oscillator circuits connected through linear networks which operate in synchronous manner at a single fundamental frequency. They can be used for a variety of purposes. Multidevice oscillators with a global coupling network are applied for power combination at the fundamental frequency, or at a given harmonic component of this frequency. On the other hand, one- and two-dimensional oscillator systems with nearest-neighbor coupling can be used for beam steering in phased arrays. The beam steering capability comes from the fact that it is possible to synthesize a constant phase shift progression with a very simple tuning procedure by varying the tuning voltages of the peripheral elements only.

The autonomous circuits must contain amplitude-sensitive devices to enable the self-sustained oscillation: that is, an oscillation that does not grow unboundedly (which would be unphysical) or decays to zero. Thus, they must necessarily be nonlinear. The analysis of autonomous circuits is difficult due to this inherent nonlinearity and the usual coexistence of the oscillatory solution with a mathematical solution for which the circuit does not oscillate. As a simple example, consider the case of a free-running oscillator, which can always be solved for a dc solution even when the oscillatory solution is the only solution observed physically. The physical solutions are capable of recovering from the small perturbations, that are always present in real life, coming from noise or small fluctuations. They are robust versus small perturbations or *stable*. In fact, the stability analysis of a given mathematical solution is the verification of its physical existence. This analysis should be carried out in all circuits containing nonlinear devices and it is essential in autonomous