Chapter 10
Inventions of Monolithic Microwave Integrated Circuits

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ABSTRACT

This chapter deals with the concept of first time right IC. A development of subsystems for wireless application is used as test case. The subsystems are Low Noise Amplifier (LNA), Medium Power Amplifier (MPA) and Variable Signal Generator (VSG). Several issues such as suitable multiband design flow and high speed switch must be solved. A new design methodology of integrated circuits for multiband application is presented. The design methodology is modified from a typical Monolithic Microwave Integrated Circuit (MMIC) flow. Core based design, parasitic aware approach and power constrained optimization are introduced into the new design flow. The same core circuit topology is used as main block to design 2.4 GHz and 3.5 GHz LNA and MPA. A power constrained optimization is applied to a test case amplifier i.e. broadband amplifier to get the optimized RF performance. The optimization is simulation-based technique. A 0.15 μm 85 GHz PHEMT is used in designing the LNA, MPA and broadband amplifier. This chapter also introduces the inventions of Voltage Controlled Oscillator (VCO), Mixer, Low Noise Amplifiers (LNA), Power Amplifiers (PA) and Transmit-Receive Switch (T/R). These circuits are crucial components for RF and Microwave front-end integrated circuits. The elements of inventions of circuits are clearly explained. The inventions reflect the requirement or the need of solving current problem using available technology.

INTRODUCTION

Due to increase in demand of multiband solution, it is therefore necessary to understand design methodology of multiband transceiver. A typical Monolithic Microwave integrated circuit (MMIC) flow (Bahl, 2005) is normally used in designing MMIC and Radio Frequency Integrated Circuit (RFIC). It has a comprehensive flow starting from defining specification until two-dimensional analysis of layout. Nevertheless, the flow requires many iterations in designing stage, due to uncertainty in layout and parasitic.

DOI: 10.4018/978-1-60566-886-4.ch010
The design flow does not specifically cater for multiband design. This will be discussed in this chapter. Apart from the design flow, core circuit, LNA, MPA and switch design will be also covered. This is important for ‘First time right IC’ concept.

In designing Monolithic Microwave Integrated Circuit (MMIC) for commercial needs or research endeavor, the knowledge of the current state of the art of current work is important. Nevertheless, one must be cautious not to infringe the design or inventions. This chapter has five main circuits or inventions to be discussed; the VCO, Mixer, LNA, PA and T/R Switch. These five circuits are arranged under different topics for clarity. Multiband and reconfigurable concept is current state of the arts and also future trend for integrated circuit solution to support advanced technology such as 4-G technology.

FIRST TIME RIGHT IC CONCEPT

Background

Design Flow

A Typical MMIC or RFIC design flow is to start with topology analysis with respect to specifications. Topology is then simulated at schematic level to verify the performance against the specification. Selection of device (transistor) size is important for bandwidth, DC power consumption, noise figure and non linear performance tradeoff. In addition to the tradeoff, the right size of devices can facilitate easier input and output matching. The design is then convert into the layout and post-layout simulation which is could be in the form of 2-D simulation is done to verify the performance against the schematic simulation or specifications. If the performance is not similar to the specifications, the design layout has to be modified. The process is repeated until the specifications are met. The flow (Bahl, 2005) is reproduced in Figure 1 for clarification.

Smith chart (Smith, 1969) is one of the earliest synthesis tools for impedance matching for microwave transistor amplifier.

One of the earliest work employing smith chart as part of synthesis technique is reported in (Sidduqi, 1979). The work employs smith chart to locate the noise and gain contour, the matching circuit is then synthesized using numerical calculation. The technique can be divided into three major parts, generation of the broadband impedances to be presented at the device input and output terminals for obtaining, respectively, the gain and output power performance as a function of frequency, construction of a positive real driving point impedance function to represent the above impedances, and realization of a lossless lumped-distributed network terminated in a 50 Ω resistance, derived from the impedances. The impedances is derived using reverse application of the asymptotic techniques. The impedance that leads to instability must be avoided and magnitude and phase of the impedance must be compatible.

Recent synthesis tool released by Applied Computational Science (ACS) (Henkes, 2005) used smith chart heavily in automate low noise amplifier design. Couple with simulation tool (analysis tool), a design such as LNA can be performed in only a matter of minutes. However, the synthesis tool is meant to be used for RF discrete design i.e. not RFIC.

Eagleware-Elanix produces two synthesis modules (AMPLIFIER and MIXER) (Eagleware-Elanix, 2005) in year 2005. The MIXER synthesis module allows the user to design and analyze mixer configuration. 11 topologies of the mixers are available. While, the AMPLIFIER synthesis module facilitates