Chapter 9
The Design and Modeling of 30 GHz Microwave Front-End

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ABSTRACT
This chapter aims to discuss a millimeter wave integrated circuit (MMWIC) in frequency of 30 GHz especially switch (SPDT), medium power amplifier (MPA) and low noise amplifier (LNA). The switch is developed using a commercial 0.15 µm GaAs pHEMT technology. It achieves low loss and high isolation for millimeter wave applications. The circuit and layout drawing of SPDT switch are done by using Advanced Design System (ADS) software. The layout is verified by running the Design Rules Check (DRC) to check and clear all the errors. At the operating frequency of 30 GHz, the reported SPDT switch has 1.470 dB insertion loss and 37.455 dB of isolation. It also demonstrates 26.00 dBm of input P1dB gain compression point (P1dB) and 22.975 dBm of output P1dB. At a supply voltage of 3.0 V and 30 GHz operating frequency, this two-stage LNA achieves an associated gain of 21.628 dB, noise figure (NF) of 2.509 dB and output referred 1-dB compression point (P1dB) of -11.0 dBm, the total power consumptions for the LNA is 174 mW. At a supply voltage of 6.0 V and 30 GHz operating frequency, a 2-stage MPA achieves a linear gain (S21) of 13.236 dB, P1dB of 22.5 dBm, power gain of 11.055 dB and the PAE of 14.606%. The total power consumption for the MPA is 1.122 W. The 30 GHz LNA and PA can be applied in direct broadcast satellite (DBS), automotive radar transmitter and receiver.

INTRODUCTION
Microwave switches are essential elements for a number of widely varying applications, ranging from highly sophisticated space communications systems to more common applications simply requiring the switching of an RF signal from one part to another. Circuits that switch RF and microwave signals are very useful, especially for applications such as phased-array radar and instrumentation. The best MMIC technology for switches is the FET because of the inherent isolation between the gate contact and the

DOI: 10.4018/978-1-60566-886-4.ch009
source and drain contacts, and because the gate draws virtually zero current in both control states (on and off) (Ayasli, 1982).

GaAs FET-based switches have been the dominant technology for the RF transmit/receive (TxRx) switch due to their low DC power consumption (Feng Jung Huang et. al., 2001). SPDT switches are also an integral part of transceivers, where they are used to switch a device between receiver and transmitter modes, and receiver front end for diversity application (Ketterl, et. al., 2004).

The 30 GHz low noise and power amplifier are mostly used in direct broadcast satellite (DSB) and automotive radar. Direct Broadcast Satellite (DBS) is a satellite-delivered program service meant for home reception. DBS programming is in most respects, the same as that available to cable television subscribers.

MMIC power amplifier is much more complicated than the small-signal amplifier design because the larger voltages and currents within the circuit can cause the MMIC components to behave nonlinearly. The simulation of a circuit with nonlinear components no longer has a unique solution but require iterative techniques.

Advanced Design System (ADS) software is used to implement the design from schematic, layout design and analysis level. The objectives for this work are as follows:

i. To study and understand switch function, performances and applications.
ii. To compare the simulation results between switch without distributed components and with distributed components.
iii. To integrate the SPDT switch, MPA and LNA.

This chapter is organized as follows. Introduction presents the overview of the project’s scope. Background emphasizes the basic theory of designing the switch. Design methodology section details the method and the mathematical calculation are presented which clearly showed the outlined of the switch, LNA and MPA design. Results is the section that showed the result and the discussion of the switch, low noise amplifier and medium power amplifier designs.

Final section gave the overall conclusion of this chapter and discussed the future challenges.

BACKGROUND

FET Switch Device Behaviors

In most processes, the FET can be accurately modeled by an on-resistance, $R_{on}$, and an off-capacitance, $C_{off}$, in these regimes and at frequencies representative of the communication systems mentioned. $C_{off}$ is defined as the total capacitance from drain-to-source with the gate biased by a high-impedance source. Both parameters affect the switching speed, insertion loss and isolation of a switch, so a FET process can be evaluated for its efficacy as a switch process by the product of $R_{on}$-$C_{off}$. Table 1 compares the $R_{on}$-$C_{off}$ figure-of-merit from the several process technologies (Dylan Kelly et. al., 2005).

Insertion loss of GaAs switch IC can be estimated by the product of the off-state capacitance and the on resistance of the employed FET (Y. Ayasli, 1982). Shortening the gate length of the FET is effective to reduce this product. However decreasing the insertion loss is limited due to the directly coupled drain to source capacitance, namely $C_{ds}$ (T. Tanaka et. al., 1997). It can be expected that the insertion loss will
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