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Radio Frequency Power Amplifiers for Software Defined Radio

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ABSTRACT

Power amplifiers (PA) for modern wireless communications standards typically state non-constant amplitude modulation schemes to use the constricted frequency spectrum author efficiently and large bandwidths to meet the claim for higher data rates. Not with standing, to forgather the spectral and modulation requirements, highly additive PAs are required. With the reinforced intensify of CMOS transistors, highly effective switched PAs, such as class-D and class-E, feature gained accrued occupy in polar modulation and out phasing, Transmitters for high rate data communications (e.g. WiFi and WiMAX) need to simultaneously meet multiple conflicting requirements: high output power, efficiency and PAPR (Peak to Average Power Ratio). Out phasing is the used technique for realizing such PAs in low-cost, digital CMOS.

The improvement in low-cost complementary metal-oxide-semiconductor (CMOS) technology has made it a normal option for radio frequency (RF) transceivers in wireless applications. Its advance has enabled the integration of baseband and different functional blocks. CMOS technology will be the farthest feasible solution for full integration on a single die, decrease package form factors and their costs. In addition, CMOS technology supply good thermal characteristics and a low-cost advantage paid to its matured process technology as well as a high level of integration. However, still CMOS power amplifiers (PAs)

design is a challenging task for full integration. Although some efforts for full integration have been reported, they are only for PAs with low output power.

High-efficiency performance is one of the utmost important requirements of power amplifiers (PAs) for wireless applications. However, the design of highly efficient CMOS PAs for watt-level applications is a challenging task. This dissertation focuses on the development of the design method for highly efficient CMOS PAs to overcome the fundamental difficulties presented by CMOS technology.

Although the demands for the design of high efficiency switching PAs have quickly increased through the last decade, their implementations using CMOS technology are highly challenging tasks for wireless applications because of soft breakdown voltage and lossy substrate. This dissertation consists of two contributions for fully integrated highly efficient watt-level switching CMOS PAs.

The voltage-mode Class-D amplifier is one in which the output transistors are turn on as switches. The produced voltage waveform is forward to a series resonator which offers high impedance at all frequencies excepting the resonant frequency, consequently removing the out-of-band signals. Since the two transistors are turned on and off alternately, a voltage-mode class-D amplifier can be border as a voltage controlled voltage source, which run efficiently when supply a series resonator. This high efficiency characteristic, can be preserve even if driven by non-periodic digital signals, so long as the adverse currents appearing in this situation can be provided by the active devices or parallel diodes during the ON-state.

The output power of CMOS class-D RF PAs has, pending lately, been lower than +30 dBm. To realize higher output power, either low load impedance or a high supply voltage can be applied to obtain high voltage swing, i.e. a high impedance transformation ratio, is necessary. Using a high impedance transformation ratio can outcome in low efficiency, particularly with on-chip matching networks, and bandwidth reduction.

In chapter 3, the designing and the simulation for the voltage-mode class-D RF PA which can derive at a 5V/3V supply and have output power +27.1/+24.6 dBm with 32%/37.2% PAE in a standard 350/130 nm CMOS technology. The proposed PA can operate at 2.4 GHz and gives high PAE with high output power with respect to the other published class D PAs where they used eight or four power stages of class D PA and combined them with transformer or combiner. The propose power amplifier uses only one power stage with only one supply voltage. Moreover, our amplifier overcomes the effect of input source resistance.

In chapter 4, the design and the simulation for the current-mode class- D RF PA which can derive at a 5V/3V supply and have output power +29.5/+26.5 dBm with 73.63%/79.75% PAE in a standard 350/130 nm CMOS technology. The proposed PA can operate at 2.4 GHz and gives high PAE with high output power and have largest1dB bandwidth with respect to the other published class D PAs, also the CMCD amplifier is more attractive for RF applications than the

VMCD amplifier, due to higher levels of efficiency and output power achieved. Moreover, our amplifier overcomes the effect of input source resistance,

chapter 5, includes the conclusions and the future work.

Key Words___*software defined radio, radio frequency, CMOS, power amplifier, switching-mode, class-D, linearization, supply-voltage , high efficiency techniques, power losses, voltage-mode, current-mode, PAE, cadence tools.*

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CHAPTER ONE

INTRODUCTION

1.1 Brief history of radio

The era of wireless communication began when Heinrich Hertz prove the Maxwell's theory of electromagnetism that predicted the existence of electromagnetic waves. In 1887, Hertz expound the transmission and reception of electromagnetic waves as foresee by Maxwell through his experiment. His radio transmitter system consisted of a high voltage induction coil, a condenser and two brass conductors separated by a tiny gap to cause a spark discharge.

Once a spark was generated, a conducting path was formed between the spark-gap and the charge could rapidly oscillate back and for that a frequency specified by the values of the capacitor and the induction coil. The receiver was a loop made from copper wire with a small gap in the loop. When the spark-gap transmitter produced a spark, a small spark was seen to bind the gap in the receiving coil. He could detect the radio waves few meters from the transmitter in his lab.

At that time Hertz thought his work has no practical application [1], and it was Guglielmo Marconi who used radio waves for communication and commercialized a practical system. Using an improved spark-gap transmitter, coherer-receiver and other various inventions at that time, he was able to transmit radio signals for about a mile at the end of 1895. In 1897, he affirmed world's first radio station in England. In the same year, he formed his first company "Wireless Telegraph and Signal Company" in Britain. Marconi basically assembled inventions from Nikola Tesla, Oliver Lodge, Edouard Branly, etc., and used them to improve his radio system. Entrepreneur Marconi's company was able to transmit first trans-Atlantic radio signal in 1901, although the claim is later disputed [2]. He established the first permanent transatlantic wireless services from Clifden, Ireland to Glace Bay, Nova Scotia, Canada in 1907.

The importance and usefulness of wireless communication was further highlighted following the submergence of the RMS Titanic in 1912, including communications between two operators on the sinking ship and nearby vessels, and communications to support stations staggering the survivors [3]. Distress signal using wireless telegraphy from the Titanic made a big impression on the public touching the advantage of wireless communications.

The contrivance of the triode vacuum tubes by Lee De Forest in 1907 was a great step forward toward better transmitters and receivers. One terminal of the triode, called grid, controlled the current and made amplification possible. This allowed for amplitude modulation of a continuous wave signal and made voice transmission practical. Transmission with continuous wave signal is narrowband whereas spark-gap transmitters emitted wideband signals causing a serious interference problem. With an improved triode, the transmitters were made more power efficient. In 1921, the Detroit police experimented with one way voice transmission to cars. Two-way police radio, with the equipment occupying most of the car trunk, began in mid-1930s.

World War II resulted in the mass production of radio equipment in order to equip the increasing number of aircrafts and ships. The widespread use of wireless communication using telegraph, broadcasting, telephones, and point to point radio links, was accelerated during and after the war.

The invention of the transistor, drastically reducing the size and power consumption of the radio system, started a new era in electronics. By 1966, the first pocket-sized mobile phones were produced. After 1980, cellular phones and cordless phones became very popular and enjoyed very rapid growth till date.

Today, developments in radio technology are as exciting as Marconi's first transatlantic wireless communication. Recently, the International Telecommunication Union (ITU) predicted that the number of mobile cellular subscribers worldwide will reach the 5 billion mark by the end of 2010. This is an astonishing number, comparing with the world population of 6.87 billion. Another exciting example of the use of radio waves is in the space exploration. For example, NASA collects observations from the twin Voyager I and II spacecraft, which are over 12 billion kilometers away from the earth and at the edge of our solar system. It takes over 14 hours for the signal to reach the earth from the Voyager I.

1.2Software defined radio (SDR) technology

1.2.1 SDR challenges and requirements

Software Defined Radio (SDR) is a radio communication technology that is established on software communication protocols instead of hardwired applications. Frequency band, air interface protocol and implementation can be better with software download and update instead of a complete hardware commutation[4].

The main conception is how elasticity the radio waveform can be varied through changing software and without change the SDR platform. A SDR is qualified for existence reconfigured or reprogrammed to operate with various waveforms and protocols. These waveforms and protocols can include a number of different parts, including modulation techniques, security and performance characteristics defined in software as part of the waveform itself.

Most traditional radio architectures provide wireless communication equipment that lets subscribers to download unprecedented applications such as reactive games, banking and ticketing applications, wireless cooperation etc. However, such customizability will not stay restricted to the application layer only, but will extension to the lower layer and radio application of communication devices. In addition, the equipment operates a single band or range of frequencies but there are many applications where multiple frequencies of operations are desired. Thus multiple radios are utilized; each designed to operate in one fixed band. A multiband radio has the power to operate on two or more bands either sequentially or simultaneously, as in the