A 60W Compact Highly Efficient Wideband Class-E Power Amplifier

A Thesis submitted to the
Electrical Engineering, Mathematics and Computer Science Department of
Delft University of Technology,
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Electrical Engineering

By

Kanjun Shi

Thesis Supervisors:

Dr. Leo de Vreede (TU Delft)

M.Sc. David A. Calvillo-Cortés (TU Delft)

Dr. Fred van Rijs (NXP)

August 2010

ACKNOWLEDGEMENTS

The one year master project is a hard but wonderful journey to me. And till now, all the works in the year makes into some successful results and a thesis. This section is dedicated to people who made all these things possible. Without the help of these people, the project and thesis cannot be finished.

On top of the list is my supervisor Dr. Leo de Vreede. I would like to express my deepest gratitude to him, for helping me identify research direction, allowing me to express my fullest potential for research and guiding me through the research process. What I learned from him is much more than just the technical knowledge. He himself sets the example of how to be a good engineer and scientist and how to work efficiently within a team.

A good supervisor is the one who gives you inspirations when you are stuck; who comforts you when you feel bad about yourself; who points out your weakness when you feel too good and who is willing to help whenever you need. Leo is a great supervisor in all these senses.

Lots of thanks go to David Cavillo. As the co-mentor, David has given me all kinds of supports throughout the project. His strict and earnest attitude on the research impresses me very much, which is also a very important factor of achieving the successful design. Many thanks go to Mauro Marchetti, for providing me the amazing measurement system which makes my life easier. Thanks also go to Marco Pelk, Nan Li, Lai Jiang for answering me quite a lot of basic questions.

I would like to thank NXP semiconductors, which gives me the financial support to the project. Also, Igor Blednov, Yuri Volokhine, Fred van Rijs, Thomas Roedle and Michel de Langen from NXP gave lots of useful and nice inputs. Thanks go to NXP technicians at pilot line for their excellent assembling skills. Without them, the work cannot be feasible.

Thanks my roommates for giving me the “normal” social life, who are Bo Wu, Yinan Wang, Huaiyu Ye and Tao Zhang.

My strongest gratitude are given to my family. Your continuous loves, cares, supports and encouragements are the best things in my life.

Kanjun Shi

Delft, the Netherlands

August 5th, 2010

ABSTRACT

With the rapid growth of wireless communication systems, there is more and more demand for radio frequency power amplifiers (RFPAs) in base stations to be power-efficient so as to reduce the cooling and electrical power cost. Besides the efficient requirement, wide-band working frequency and compact PCB size are also attractive for cutting more cost. This thesis deals with a switch-mode Class E power amplifier which provides wide-band, highly efficient and compact size performance, with a 60W GaN HEMT device. A mathematical model for Class E amplifier is presented and analyzed. Based on the model, a novel design procedure for wide-band power amplifier design is proposed. The input/output matching networks in the amplifier are built by bondwires and pre-matching capacitors so as to give an extremely compact size. The 60W compact wide-band power amplifier is then implemented with PCB to verify the concept. A wide-band measured output power performance is observed over 1.7GHz - 2.3GHz in the range of 40-65W and the measured drain efficiency is between 66% and 74%; measured PAE is between 61% and 70%. Transducer power gain is 12dB ± 1dB over the frequency range. Besides the amplifier, additional work is about large signal device modeling with PolyHarmonic Distortion model which is based on acquiring X-parameters of a device.

CONTENTS