[ENGR596] FINAL REPORT

Youngseok Lee, youngseo@usc.edu, 4930239194

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1 INTRODUCTION

This company KMW Communications(Korea MicroWave, aka KMW Inc.) is a global leading supplier in the mobile telecommunications infrastructure market. KMW Inc., designs, develops, and manufactures full range of RF & Air Interface Product from the component to the system level.

KMW Inc., has the competitive advantage with superior Mobile Telecommunications Technology, LED Photonic Technology, Network Technology and other future technologies to create maximize a synergy effect.

The Headquarter of KMW Inc is located in Dongtan-myun, Hwasung-si, South Korea and its USA branch(KMW USA) is located in Fullerton, California. The number of employees of KMW exceeds a thousand including research design engineers, manufacturing assistants, and administrative officers.

KMW USA in Fullerton has teams of research engineers for its RF product solutions. Main customers include Alcatel-Lucent, At&t, Sprint, and other carriers in USA. The main product that KMW USA designs is called Remote Radio Head(RRH, Figure 1), a transceiver used in mobile communication base station which connects and controls the access network and Handset wirelessly. In RRH, several modules are combined independently and function as a whole system.

The research team I worked at was a team of Power Amplifier(PA). PA is an essential part for any signal transmitting devices. In order for a signal(information) to be transmitted through antenna over the long distance, a proper power should be applied so that the signal propagates the desired distance over the air. PA does the job of amplifying the ready-to-go signals by maximizing its output power while maintaining its signal integrity, gain, and other required specifications within its range of operation.

2 JOB DESCRIPTION

I have gone through three different PA design projects during my internship. It was same the fact that all of them involve designing PAs, but there were differences in performance requirements thus design procedures. In a 850MHz PA project, for instance, it was required

Figure 1: Remote Radio Head(RRH)

that the designed PA has the following specifications : Output power of 45.8 dBm, Current consumption of 3.5A(max), Complementary Cumulative Distribution Function(CCDF) Peak and 0.01% of 8.5dB(min) and 8.2dB(min), and Gain of 46.3 dB.

Among those specifications, the main design criteria for Power Amplifier often includes maximum output power, and the minimum amount of current consumption. Output power determines how good this amplifier functions correctly as amplifying its signal. Low current consumption means good power efficiency, thus saving energy and heat dissipation. Unlike other types of amplifiers, achieving a high gain may not be important as meeting power and efficiency criteria. In order to design the power amplifier in such ways, the senior design engineer changes locations of capacitive components and micro-strip pattern, aka tuning. I mainly tested measurements of how good a power amplifier improved its specifications after the tuning process and optimize its performance by additional tuning processes.

I repeat these design processes on five different bare PCB boards(Figure 2) that satisfy the PA design requirements and hand them into the system team who determines which design works best for the whole RRH system in a system view point. Moreover, the system team modifies the designed PA for manufacturing version or mass production, and the factory in South Korea finally produces the industry product for customers.

3 Work Environment

In order to do the testing and designing works, many testing equipments are necessary.

1. Signal Generator : Generates a modulated signal for appropriate input power.

2. PA PCB Board : Inputs a signal from (1) and outputs a amplified signal that meets the output power, current consumption, and other specifications.

3. Power Supply : 5V for PA Integrated Chip components, 30V for PA predrive and Doherty Amplifier.

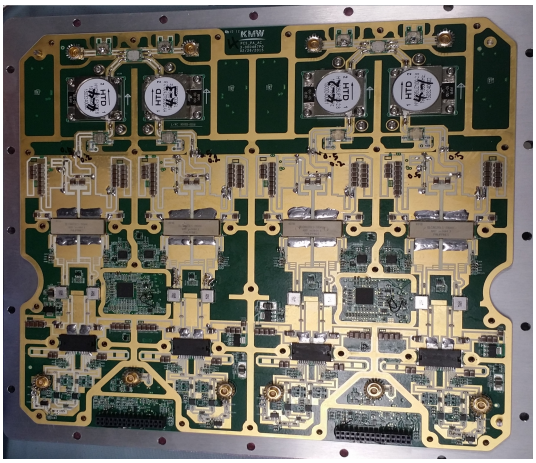

Figure 2: A Bare PA PCB Board

4. Network Analyzer : Has two ports and returns S parameters for gain and feedback factors(input and return loss). Also used for debugging a PA pattern path. For a completed PA board, two ports are connected to input and output levels, and engineers improve the gain and/or DPD feedback factors by allocating a T-Pad resistors or attenuators.

5. Signal Analyzer : Analyzes the output signal in terms of the signal integrity, CCDF factor.

6. Terminator : Terminates unused output ports by forcing them to have no reflections but all absorbs in the terminator.

7. Attenuators : Inputs a signal, attenuates the signal, and outputs it. Attenuators are necessary in PA design in order to protect testing equipments that has input power range typically up to 20W. Because PA deals with high power, unattenuated power signal could damage the measuring equipements.

8. Coupler: Has three ports : In, Out, Sampling. Coupler is used to sample the main path signal for debugging purposes. 10dB coupler only samples out 10% of input power.

9. Power sensor(meter) : Detects output power in the desired frequency and with desired offset.

Each of the environment equipment setup above is crucial, and mismatch in one component could harm its validity. Therefore, with the careful environment setup(Figure 3), each verification such as functionality, or tuning performance checkup is conducted.

4 The importance of the work to the company

PA design is application level and typically involves trial and error process. Rather than theoretical placement of components, plugging in actual circuit component is more reliable due to EM complexity in computer simulations. This means that it takes time to finally come up with prototype p0 version of the PA. The company could be faster in design

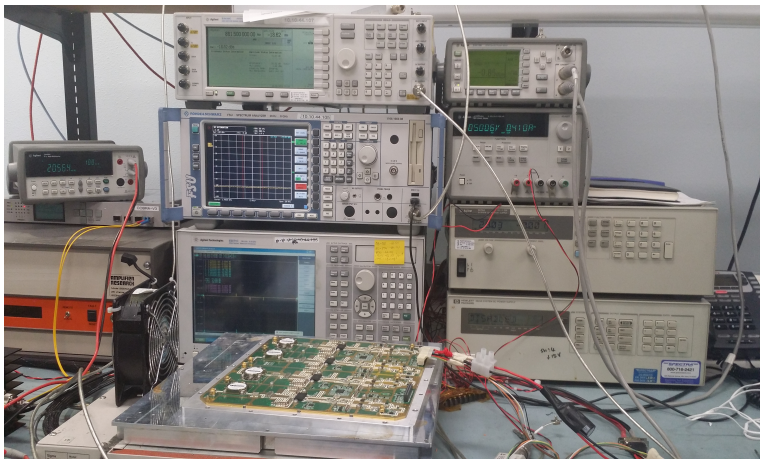

Figure 3: Work Environment

procedures by the help of intern, myself, save time, and tune more for better design.

I suggested design pattern, update the previous works by tuning, and measured performances of PA.

5 Miscellaneous

As an intern, I was exposed to other tasks that are not PA design.

1. Reliability test : The business customer of 850MHz PA wants to know how reliable the whole system is. This amplifier is placed in base stations. All sudden climate conditions may impact the performance and durability of the whole system. Thus, temperature analysis is necessary and performed in a chamber. The operating temperature is 27 degree Celsius. Because PA dissipates lots of heats, high temperature durability of each element on PA needs to be examined. The speculated elements include amplifier ICs, Control Unit chips, isolators, couplers, logic gates, capacitors, resistors, and etc. Depending on the location on PA, a variety of temperature distributed over the elements. The effect is taken into account for reliability calculating simulator. I manually analyzed the locations and temperatures of each element of PA.

2. VSPA software training : In RRH, a logic chip for digital performance is necessary. KMW Inc., plans to use a chip called the AFD4400. The AFD4400 is a programmable, high performance single chip solution for the digital front end functionality in radio systems ranging from integrated small cell base stations to remote radio units. The device integrates one ARM Cortex-A9 core along with 11 Vector Signal Processing Accelerator (VSPA) cores. Two Freescale engineers visited KMW from Austin, Texas, and held the training session for KMW's software team. I joined this training in order to see the software side of RF system design.

3. PCB Layout : Our PA layout consists of 5 layers. Each layer involves its own

functioning circuity stacked on top of each other in order to save the area. While working on the tuning process, minor modification on PCB layout structures is necessary. So the research engineers report the modifications to the PCB layout engineers in a simple CAD tool such as Draftsight. I experienced this layout drawing tool.

4. Other techniques and parts : The topics I was not able to experience in KMW Inc., are PA heat dissipation technique, Distributed Antenna System(DAS), how to determine the component locations in PA, and the EM simulation behavitors.

6 What you learned about

I have been told that there is always a gap between theory and practices. By this internship opportunity, I truly realized what this means and how the gap could be narrowed.

In EE544, power amplifier is divided to two categories; Class A,B,AB,C or Class D,E,F depending on the conduction angle. The two type differs in trade-offs between efficiency and linearity. The former type better offs at linearity but lacks at efficiency, the latter works as the opposite. KMW Inc uses a Doherty amplifier, a structure initially designed in 1930s and more popularly used in nowadays. Doherty amplifier consists of a input power divider, two PAs in parallel(Main PA and Peak PA), and two 90 degree lines at the input and the output. The peak PA is biased as a Class C, and the main PA is biased as Class A, AB, B, F, or etc. Main PA is always on and the peak PA turns on depending on the necessity of additional output power. This Doherty amplifier has good linearity and efficiency. Many other PA design companies in industry also work on this design for their commercial products. I also learned techniques to improve efficiency such as Chireix outphasing and envelope tracking, which might be on the market in a few years.

Apart from the theoretical gap, in practices, I learned measurement techniques using equipments for Gain, Power, Feedback, Efficiency, and etc. All of them are important and has different measuring procedures.

I learned the technique to design and tune PA by modifying capacitive components. Many times, the tuning process involves trial and error, but they are not totally random. They work in a certain manner and I experienced how to improve a parameter by an appropriate tuning.

PA design I experienced in KMW Inc., is an application level design. This means that it does not involve Integrated Circuit designs but the company purchases IC products from vendors and simply combine them together in order to design the RRH system. As a master student, I felt that it is more beneficial to work on a fundamental techniques, rather than the application one that sometimes does not involve complexity, or difficulty. It was because the application technique changes as the time goes by and possibly anyone interested could work on it, but the fundamental does not change and only skillful engineers could manage. This impression may navigate what specific topic in RF I want to work on through my graduate studies and future career in industry.