DESIGN OF RF POWER AMPLIFIER WITH DIFFERENT BIASING BASED ON GREEN DESIGN TECHNIQUE

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To my beloved mother, father and family

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ABSTRACT

Nowadays, the development of low-cost, low-power radio frequency (RF) for a base station application grows rapidly. The high power consumption of a base station is caused by poor efficiency in RF power amplifier design. The project is based on RF power amplifiers and green design technique that have been used in a variety of applications for example are the wireless communication. Green design technique is used to improve the performance of power amplifier and thus lower the power consumption. The main purpose of an RF power amplifier is to boost radio signal to a sufficient power level for transmission through the air interface from transmitter to receiver. The most important parameter is the gain, return loss, efficiency, output power and power consumption of the amplifier. This parameter is to ensure the design amplifier can work at the desired frequency. The aim of this project is to design and compare a power amplifier for base station application at 5.8 GHz operating frequency that using two different biasing network, with a power amplifier gain above 10 dB and required to achieve low power consumption. Advance Design System (ADS) software is used in power amplifier design simulation. At the end of the project, it shows that between two biasing, the passive biasing is better compared to active biasing since it produce gain of 10.857 dB and low power consumption which is 0.986 W. The output power and return loss achieved are 20.858 dBm and -44.099 dB while the Power Added Efficiency (PAE) is 24.54 %.

ABSTRAK

Pada masa kini, pembangunan peranti frekuensi radio (RF) untuk aplikasi stesen pangkalan berkos rendah dan berkuasa rendah berkembang pesat. Penggunaan kuasa yang tinggi oleh stesen pangkalan adalah disebabkan oleh kecekapan penguat kuasa (RF) yang kurang. Projek ini adalah berdasarkan kepada penguat kuasa RF dan teknik reka bentuk teknologi hijau yang telah digunakan dalam pelbagai aplikasi contohnya ialah komunikasi tanpa wayar. Teknik reka bentuk teknologi hijau digunakan untuk meningkatkan prestasi penguat kuasa dan sekaligus mengurangkan penggunaan kuasa. Tujuan utama penguat kuasa RF adalah untuk meningkatkan isyarat radio ke tahap kuasa yang mencukupi untuk penghantaran isyarat melalui udara dari penghantar kepada penerima. Parameter yang paling penting adalah gandaan, kehilangan pulangan, kecekapan, kuasa keluaran dan penggunaan kuasa. Parameter ini adalah untuk memastikan reka bentuk penguat boleh bekerja pada frekuensi yang dikehendaki. Tujuan projek ini adalah untuk mereka bentuk dan membandingkan penguat kuasa bagi aplikasi stesen pangkalan pada frekuensi 5.8 GHz yang menggunakan dua rangkaian pincangan yang berbeza, dengan gandaan penguat kuasa melebihi 10 dB dan diperlukan untuk mencapai penggunaan tenaga yang rendah. Perisisan *Advance Design System (ADS)* digunakan dalam simulasi reka bentuk penguat kuasa. Pada akhir projek ini, ia menunjukkan bahawa antara dua pincangan, pincangan pasif adalah lebih baik berbanding pincangan aktif kerana ia menghasilkan gandaan sebanyak 10.857 dB dan penggunaan kuasa yang rendah iaitu 0.986 W. Kuasa keluaran dan kehilangan pulangan dicapai adalah 20.858 dBm dan -44.099 dB manakala PAE adalah 24.54%.

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LISTS OF ABBREVIATIONS

AC	-	Alternating Current
ADS	-	Advance Design System
BJT	-	Bipolar Junction Transistor
BW	-	Bandwidth
DC	-	Direct Current
EDA	-	Electronic Design Automation
EM	-	Electromagnetic
GA	-	Available Gain
GaAs FET	-	Galium Arsenide Field Effect Transistor
Gmax	-	Maximum Transducer Gain
GP	-	Power Gain
GT	-	Transducer Gain
IEEE	-	Institute of Electrical and Electronic Engineers
IMD	-	Intermodulation Distortion
MAG	-	Maximum Available Gain
MMDS	-	Multichannel Multipoint Distribution Services
MOS	-	Metal Oxide Semiconductor
PA	-	Power Amplifier
PAE	-	Power Added Efficiency

LISTS OF SYMBOLS

C	-	Capacitor
d	-	Thickness
dB	-	Decibel
dBm	-	MiliDecibels
GHz	-	Gigahertz
K	-	Rollet's Stability Factor
mA	-	Miliampere
Mbit/s	-	Megabit per second
Mm	-	Milimeter
mW	-	MiliWatt
MW	-	MegaWatt
P	-	Power
R	-	Resistance
S	-	Scattering
S_{11}	-	Input Return Loss
S_{22}	-	Output Return Loss
S_{21}	-	Gain
S_{12}	-	Insertion Loss
V	-	Voltage
Z	-	Impedance
°	-	Degree
ε_r	-	Dielectric constant
η	-	Efficiency
Ω	-	Ohm

Π	-	Pi
Γ	-	Reflection Coefficient
λ	-	Wavelength

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CHAPTER 1

INTRODUCTION

In this chapter, an introduction with motivations and objectives of this project are present. Thus, this chapter focuses on the project background, problem statements, project objectives, scope of work and thesis outline.

1.1 Project Background

The green technology definition, in simple words, it means the technology, which is environmentally friendly, developed and used in such a way so that it doesn't disturb our environment and conserves natural resources. We may also hear green

technology being referred to as environmental technology and clean technology. In the stages of its development, the future only promises to bring bigger and better things in this field. It will in fact be a necessity of the future. A radio frequency power amplifier (RF power amplifier) is a type of electronic amplifier that converts a low-power radio-frequency signal into a higher power signal. Typically, RF power amplifiers drive the antenna of a transmitter. Biasing in electronics is the method of establishing predetermined voltages or currents at various points of an electronic circuit for the purpose of establishing proper operating conditions in electronic components.

Radio Frequency (RF) power amplifiers are commonly used in wireless communication devices such as cellular phone, radios and wireless modem amplify and transmit (RF) signals. Radio frequency transmission of an electrical signal requires corresponding power amplification for the intended transmission range. RF signals typically have a broad frequency spectrum from several Megahertz (MHz) to tens of Gigahertz (GHz) and higher. A power amplifier amplifies a radio frequency signal at the output of a transmitter prior to transmission in a small-size communication device. A typical radio transmitter uses an (RF) power amplifier to amplify outbound signals for transmission by an antenna. RF power amplifiers are generally designated to provide maximum efficiency at the maximal output power. Within the amplifier assemblies are typically the plural printed circuit boards on which components that process the RF signals are mounted. Typically, an RF power amplifier consists of an integrated circuit chip having the transistors and other circuitry associated with the amplifier and a number of off-chip components that filter the signal or provide impedance matching at a particular operating frequency. RF signals are transmitted between the various processing components.

The main purpose of this project is to design and compare different types of biasing network for RF power amplifier for base station application which operating at 5.8 GHz. In this project a 5.8 GHz frequency will be used. Important parameters for RF

power amplifier are Power Added Efficiency (PAE), gain, output power, return loss and DC power consumption.

1.2 Problem statement

In the recent years, wireless devices and mobile communication systems have increasingly become very popular. Currently, 3% of the world-wide energy is consumed by the (Information and Communication Technology) ICT infrastructure, which causes about 2% of the world-wide CO2 emissions. Today, more than four billion people in the world have access to the mobile phones. The overall energy consumption of mobile devices seems to be more than those of base-stations. Good environmental control and less energy consumption will contribute to slow down the abnormal temperature variation. Recently, green technologies that can reduce energy consumption and carbon-dioxide emission and reuse the resources have been attracting many people. Especially, green Information Communication Technology (ICT) has been studied widely to achieve high Energy Efficiency (EE), and to resolve the conflict between high demands of Quality-of-Service (QoS) and energy saving [1].

Base stations represent the main contributor to the energy consumption of a mobile cellular network. Since the traffic load on mobile networks significantly varies during a working or weekend day, it is important to quantify the influence of these variations on the base station power consumption. To reduce the energy consumption of cellular networks, precise knowledge about base station energy consumption and the influence of the traffic load on the instantaneous base station power consumption can be of great importance. Generally, it is assumed that the traffic load variations have a small influence on the power consumption of the base station [2].

Inside a base station, there is an RF power amplifier. The level of performance of RF power amplifier is determined from the bias points of an RF power amplifier. Based on the bias points of power amplifier approaches, it can evaluate value for output power, efficiency, linearity, and other parameters of power amplifier.

Without a power amplifier in a system, the receiver of a system cannot receive the full information from the transmit signal. The information signals that transmit by, the transmitter will attenuate itself and the information which is not having the full info that transmitted to the receiver also known as a loss signal. The signal can attenuate itself because of its natural consequence of signal transmission over long distances. Thus, the power amplifier can be concluded that it acts as a booster for a signal before being transmitted to ensure the receiver to receive all the signal information without any loss.

The design of RF power amplifier might have two major problems. The first problem is the lower breakdown voltage due to scaling down in technology that restricts the maximum output power and second problem is the reduced transconductance of transistors, leading to inferior power gain and poorer efficiency that leads to high power consumption.In order to solve this problem, there are many methods and technique being established and one of them is green design technique. For the green design technique, there are many method uses to achieve low power consumption. Therefore the purpose of this project is to design an RF power amplifier based on green design technique in order solve the high power consumption problem of RF power amplifier design by using different biasing network. In this project, the biasing network will be manipulated in order to achieve high efficiency [1].

1.3 Project Objective

The objective of the project is to design a 5.8 GHz green RF power amplifier with different type of biasing network. The simulation power amplifier is done by comparing between two types of biasing network by using the Advance Design System (ADS) software.

1.4 Scope of Work

The scope of works for this project is to design an RF power amplifier for a base station application which operate at the frequency of 5.8 GHz by using two different types of biasing networks.

In order to achieve the objective of this project, below are the following scopes that will be covered:

a) To study the concept of power amplifier and green technique
b) All parts of the design are operating at 5.8 GHz
c) The power amplifier will be simulated by using the Advance Design System (ADS).
d) Selecting the suitable transistor to be used for the design
e) The analysis of the power amplifier will be made based on parameter such as stability, PAE, DC power consumption, return loss, gain, and output power.
f) Compare the performance of power amplifier with different biasing network.

g) Compare the calculated value and simulation value of the parameter state above.

1.5 Thesis Outline

This thesis is a document that delivers the ideas generated and the concept applied. In chapter one briefly introduces the overall of the project. The introduction consists of the project background, objective, problem statement, scopes and thesis outline.

Meanwhile, chapter two contains the literature review of the power amplifier and green technique. It discusses the researches done upon the related project, and data obtained through journals, books, magazine, and internet.

Chapter three briefing more about power amplifier that includes the type of matching networks, a type of transistor, types of biasing network and more details on the power amplifier design.

Chapter four describes the methodology of the project, which includes the project flow and its functional block diagram. It also discusses the methods used for the project such as software applied, hardware and the reasons behind it.