BALANCED MIXER DESIGN FOR WIMAX TRANCEIVER APPLICATION

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"I hereby declare that this report is the result of my own work except for quotes as cited in the references"

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ABSTRACT

The aim for this project is to design a 3.5GHz balanced mixer for WiMAX transceiver application. Mixers are used for frequency conversion and are critical components in modern Radio Frequency (RF) systems. A frequency mixer converts RF power at one frequency into power at another frequency to make signal processing easier and also inexpensive. Mixers rely on non linear relations between voltage and current to provide the multiple elements. Passive element that is used for the mixer circuit is BAT60A silicon schottky diode by Infineon. Datasheet can be view at Appendix A. Balanced mixers require hybrids, which will determine the bandwidth and overall performance of the mixer. Futhermore, single balanced mixer topology is choosed to make sure that the passive element produced the desired signal dan give simplicity to the design. The mixer circuit is design by using Advance Design System (ADS) software. This software is related with the circuit creation design which provide design tools and simulations. The design is built on FR4 board with specification of dielectric constant, $\varepsilon_r = 4.3$. The circuit is test using network analyzer and Automatic Gain Control (AGC). The design is test for return loss and gain and isolation.

ABSTRAK

Tujuan projek ini adalah untuk mereka pengadun frekuensi terimbang pada frekuensi 3.5GHz untuk aplkasi penerima WiMAX. Pengadun frekuensi digunakan untuk menukar frekuensi dan berfungsi sebagai komponen yang penting dalam sistem radio fekuensi moden. Frekuensi pengadun akan menukar kuasa Frekuensi Radio (RF) pada satu frekuensi kepada kuasa pada frekuensi lain supaya pemprosesan isyarat menjadi lebih ringkas dan kos lebih berpatutan. Pengadun frequensi biasanya memerlukan hubungan tidak lelurus antara voltan dan arus untuk memberi elemen berganda. Elemen pasif yang digunakan untuk litar pengadun ini ialah BAT60A silikon diod shottky dari Infineon. Pengadun terimbang memerlukan baluns yang akan menentukan jalur lebar dan prestasi pengadun ini. Tambahan pula, topologi baluns tunggal dipilih untuk memastikan elemen pasif itu menghasilkan isyarat yang diigini disamping membawa kepada litar yang lebih ringkas pada rekaan. Litar pengadun frekuensi ini direka menggunakan perisian Advanced Design System (ADS). Perisian ini biasanya diguna pakai untuk membina litar disamping menyediakan perkakasan rekaan dan simulasi. Rekaan litar dibina di atas papan FR4 dengan spesifikasi dielektrik pemalar bersamaan, $\varepsilon_r = 4.3$. Eksperimen untuk menguji litar ini dijalankan dengan menggunakan penganalisis rangkaian dan kawalan gandaan automatik. Parameter rekaan yang diuji adalah merangkumi kehilangan kembali, dapatan dan pengasingan.

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LIST OF ABBREVIATION

WiMAX	-	Worldwide Iteroperability for Microwave Access
LTE	-	Long-Term Evolution
MAN	-	Metropolitan Area Network
ADS	-	Advanced Design System
AGC	-	Automatic Gain Control
OFDMA	-	Orthogonal Frequency Division Multiple Access
DC	-	Direct Current
PSM	-	Projek Sarjana Muda
RF	-	Radio Frequency
LO	-	Local Oscillator
IF	-	Intermediate Frequency
AM	-	Amplitude Modulation
dB	-	Decibel
VSWR	-	Voltage Standing Wave Ratio
BPF	-	Bandpass Filter
SMIC	-	Semicoductor Manufacturing International Corporation
CMOS	-	Complementary Metal-Oxide Semiconductor
RFIC	-	Radio Frequency Integrated Circuit
IEEE	-	Institute of Electrical and Electronic Engineers

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CHAPTER I

INTRODUCTION

1.1 Project Introduction

This project is developed to design a balanced mixer mainly for application of Wireless Interoperability for Microwave Access (WiMAX) transceiver. Mixer is a devices which is design to generate either sum or difference in frequency at output port when two different input frequencies are injected into the other two ports of the circuit. Since WiMAX operated at system profile band of 3.5GHz, the mixer is design to satisfy this requirements. Single balanced mixers is choose for this project considering as the most practical mixer because most diode mixer at microwave frequencies are balanced. Commercially available balanced mixers are small, lightweight, inexpensive, broadband components. In RF application, their good spurious-response properties are essential. Furthermore, in system where LO and RF overlap, balanced mixer must be used, because it is impossible to separate Local Oscillator (LO) from the Radio Frequency (RF) by filtering.

1.2 Objective

i. To design and simulate of single balanced mixer using advance design system (ADS).
ii. To develop balanced mixer at 3.5GHz for WiMAX application.

1.3 Problem Statement

The WiMAX market continues to acquire momentum with technology similar to Long-Term Evolution (LTE) Technology. Furthermore, WiMAX technology which offer fixed data rate and triple plays service needs a good support system. To achieve that, a high performance transceiver is needed in order to get a better reception and signal. To overcome the issue, a mixer with high linearity is design. This is because mixer is an essential part in the system which can effect overall sysem performance. For this research, single balanced mixer is developed to overcome the issue considering the challenges related with earlier version of wired and wireless access network.

1.4 Scope of Work

- Software: ADS
- Hardware: AGC and Microwave Measurement Technique
- Understanding mixer parameter and structure.
- Design and analyze the mixer

According to the scope of work in Figure 1.1, this project is divided into two stages which are software and hardware. For software, it is decided to use ADS sofware which is a software specifically use to design microwave and radio frequency. This software is more practical and easier to use for designing RF circuit purpose. It has the ability to change component parameter, add Scattering parameter, plot magnitude parameter, tuning parameter, tuning with smith chart and so on.

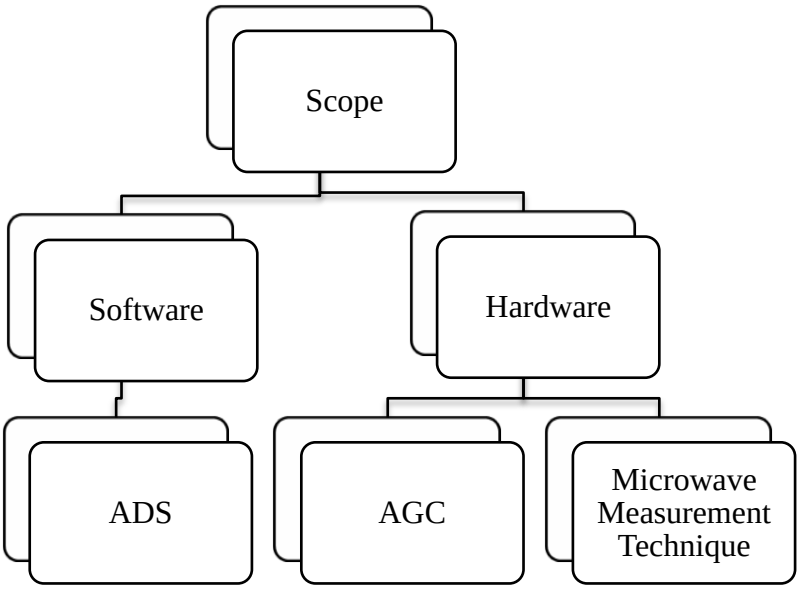

Figure 1.1: Project Scope of Work

For the first stage, the calculation is done for theoritical value for each of the parameters in the mixer circuit. This value is important for comparison with the simulation result and experimental result obtain later. The calculation involved are for the widths and lengths of the RF microstrip circuit in accordance to the value of the represented components. Then, the design and simulation process will be developed to match the design specification by using the ADS software. The design is start with quadrature hybrid coupler circuit. This circuit is essential to split power into two equal magnitude. Then, bandpass filter is designed to reject unwanted signal and obtain the right resonance frequency and obtain wider bandwidth.

Lastly, a matching circuit is designed to combined the coupler, diode pair and bandpass filter. The adjustment and tuning of the parameter values is done at this stage if necessary to achieve the best result. When the simulation result is satisfying and acceptable, the circuit is then fabricate on FR4 microstrip board. Then, for the last stage, testing and analysing the circuit is done by using Automatic Gain Controller (AGC) and microwave measurement technique. Device used for the measurement is network analyzer. The analyzer can measure each port loss and isolation. Most of the methods to be described are based on the wave character of high-frequency currents, rather than on the low-frequency techniques of direct determination of current or voltage. The techniques to be described are grouped under four main headings which are; power generation and measurement, wavelength and frequency measurements, measurement of impedance and standing waves and attenuation and radiation measurements. The results of the theoritical, simulation and experimental are then tabulated for comparison, verification and analysis.

1.5 Project Methodology

According to project methodology in Figure 1.2 below, the project start with literature review. The knowledge about the project scope and the area of research and the development of the current research is the main point of this stage. Literature review is done with journal , article, reference books and other source from the internet. The advantage and disadvantage of the previous work is study and compare to obtain a better research result. The research is mostly referred and compared to journal [1] and journal [2].

In mixer design part, the mixer is design using ADS software. The design part is including calculation of the mixer parameter before the parameters are testing it the simulation until the design meets the requirements needed. The design step in ADS is done part by part to ensure the circuit in each part is fullfill the purposed project parameter. The step are including designing coupler, matching circuit and bandpass filter. Then, all the parts is combined together and the final result is ready to be verify.

Lastly, this research will proceed to the next stage which is circuit fabricating. This step should start in the PSM II. The circuit will be fabricate on FR4 board with permitivity of $\varepsilon r=4.3$. The items need for the circuit are FR4 board, two units of diodes and three units of SMA connectors. After circuit fabricating is done, the circuit is tested with AGC and microwave measurement techniques in the lab. The result obtained is then verified by comparing all the result from theoritical value, simulation value, journal and experimental value.

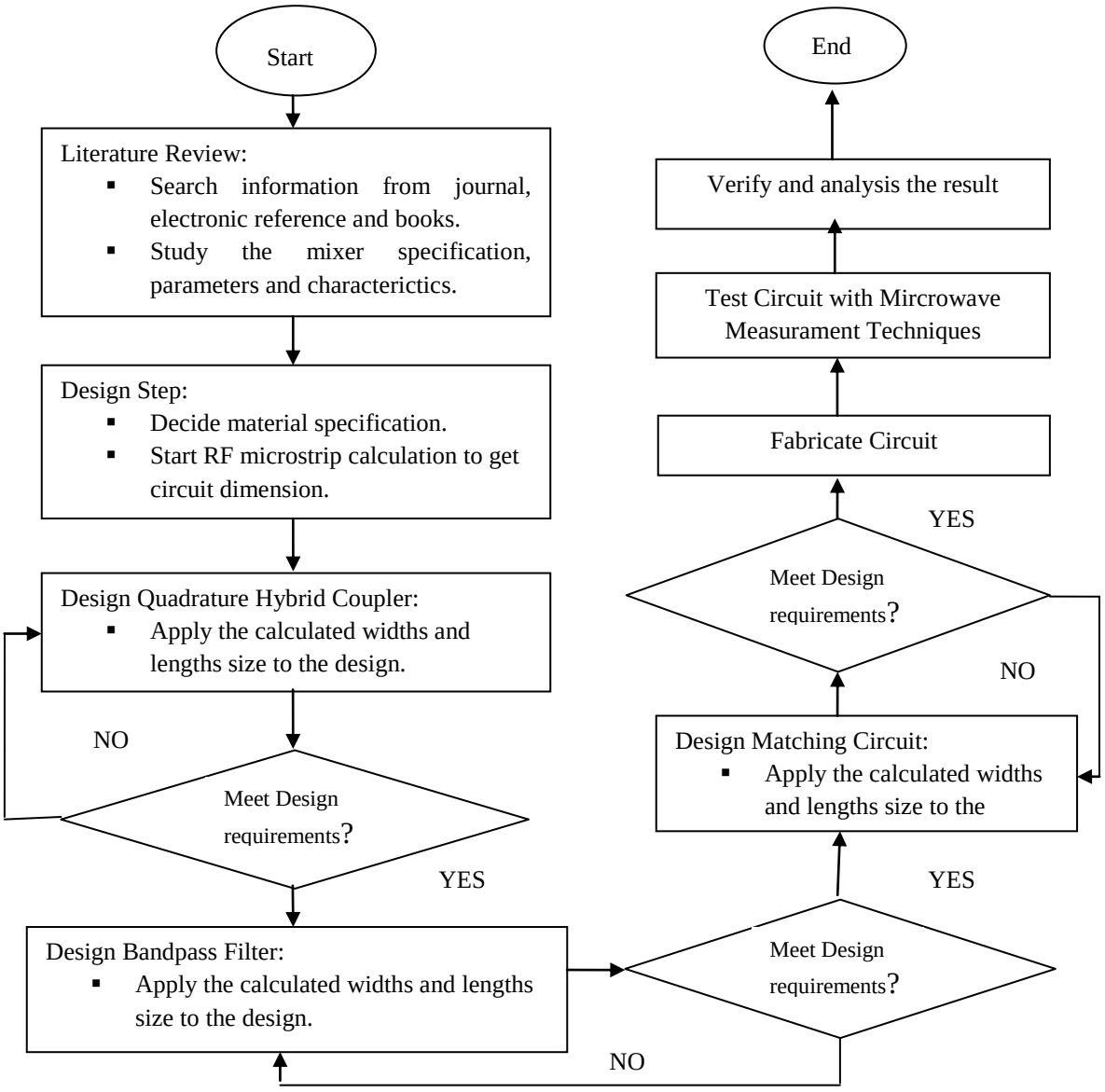

Figure 1.2: Project Flow Chart

1.6 Expected Result

Table 1.1 below shows the expected result for single balanced mixer for the final result. The return loss is expected to be in range 20 to 30dB while conversion gain is expected to be in between 3 to 7dB. Meanwhile, the bandwidth should be more than 100MHz and isolation is in the range of 25 to 35dB. The expected result is setted according to the theoritical value and is used as a reference to design the project. Therefore, if the result is within the range of the expected result, this project is considered successful.

Parameter	**Value**
Return loss	20 - 30 dB
Conversion gain	3-7 dB
Bandwidth	>100MHz
Isolation	25 – 35 dB

Table 1.1: Expected Result for Single Balanced Mixer

CHAPTER 2

LITERATURE REVIEW

2.1 CHAPTER OVERVIEW

This chapter will discuss the details about the review of previous works that are related to this research related with problem, parameters, methodology and results to complete this research. The literature review is done in order to understand the problems of the research by discovering the strengths and weaknesses of the result obtained by the previous work. The review of previous work will include the definition, explaination and justification on the problem exist and methodology used.

2.2 WiMAX OVERVIEW

WiMAX is a wireless communication that transmit data between devices through radio frequency signal. WIMAX in wirelesss digital telecommunication also known as IEEE 802.16e[3]. It is based on Orthogonal Frequency Division Multiple Access (OFDMA) modulation and it use smart antenna technique which allows simultaneous low data rate transmission for several users[4]. This technology provides mobility, coverage**,** maintainability**,** roaming services that has low deployment cost and widespread access. This technology also provide triple play service (phone, cable and electricity) in telecommunication system.

Theoritically, WiMAX coverage is about radius of 50 km at the fixed transmission station. While, WiMAX base station can cover between 5 to 10 km in average with more than 60 user can accessed it. The transmission station will transmit data from point to point over a long distances. An ideal WiMAX can support overall 70Mbps capacity of data but te bit rate will decreased as distance range increase. WiMAX has develop system profiles of licenced band spectrum of 2.3GHz, 2.5GHz and 3.5GHz for transmission[3].

Figure 2.1 below shows WiMAX system which basically, contains of two parts which are the WiMAX tower station and the WiMAX receiver station. The WiMAX tower station, is equal in concept with a cellular phone tower which can cover a large area. A WiMAX tower station uses a high bandwidth, wired connection on to get a direct connection to the network. It can also connect to other WiMAX tower using a microwave link. A transmission tower can reach coverage about 8,000 square per kilometer and make it possible to provide service to a much wider area.[5].

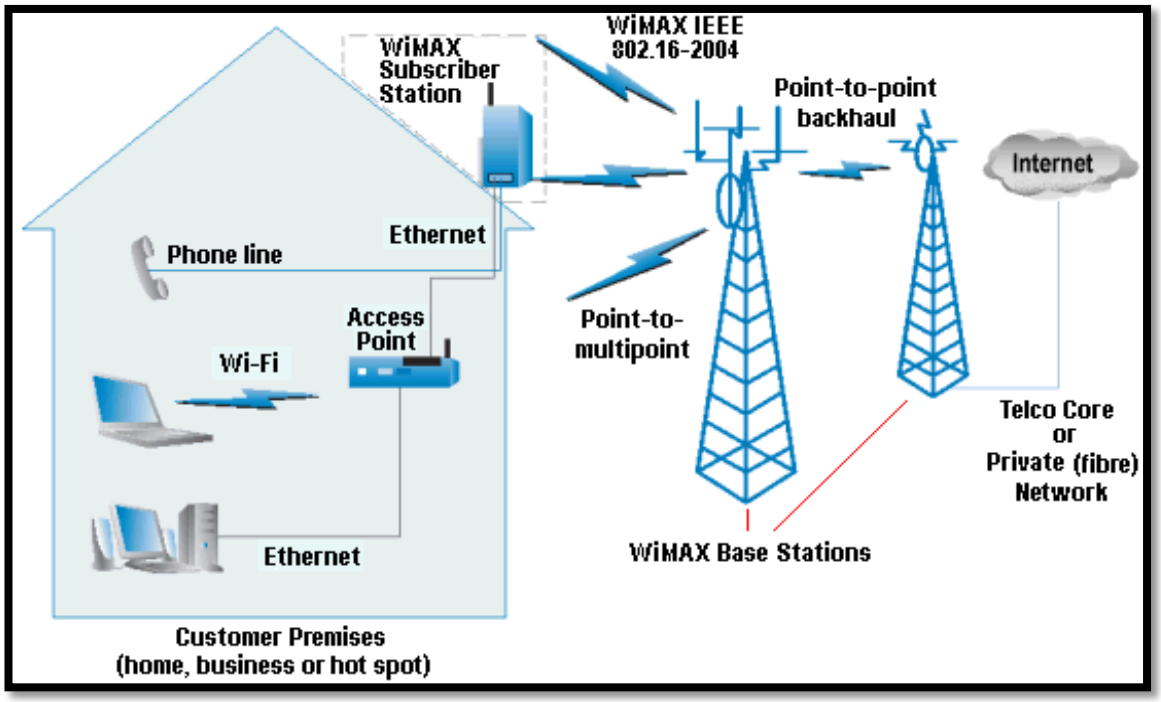

Figure 2.1: WiMAX System

2.3 MIXER OVERVIEW

2.3.1 Introduction

Since the invention of the superheterodyne receiver by Edwin Armstrong in 1917, mixers have become an important parts which control the quality of performance especially in radio communication systems. Mixer design has always been an approximate process, which at best using special-purpose computer programs[6]. The development of technology has upgrade the fidelity of the design process and lead to evolution of variety of new balun structures and topologies. These have been mostly important to monolithic circuits development. Mixers can be divided into two types that are passive and active. A major cause for frequency conversion is to get frequency except RF at the input port for amplification[7].

Mixer is a non-linear three port circuit with two inputs and one output that generates a spectrum of output frequencies equal to either the sum or difference of the two input frequencies and their harmonics[8]. The two input ports are referred as RF signal port and LO port drive whereas the output is the IF signal port. Mixers are characterized by comparing the relation between the output current, generally at the IF frequency, to the input RF voltage [9]. Figure 2.2 below shows an adealise mixer block diagram. The figure shows the mixing process of different frequency from RF and Local Oscillator (LO) input take part in mixer and result in IF frequency output.

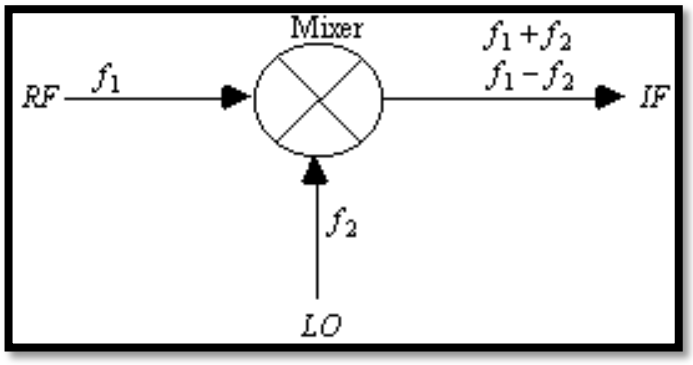

Figure 2.2: Mixer Symbol

Figure 2.3 below shows the mixer block diagram and the system flow from input to output through several process. The mixer is called the up converter if the summation frequency is used as IF and down-converter when the diffference of frequency is used. While, in a transmitter mixer is used as up-converter, which sum of frequency is utilise and the differrence of frequency is rejected. In up-converter, IF oscillator is modulated with the desired information signal and will generate the desired frequency conversion when mixed with LO signal [2]. In this research, an up-converter mixer is designed as it allows the use of single local oscillator for both receiver and transmitter which is more advantageous of the use of transceiver.