DESIGN & DEVELOPMENT OF A SINGLE POLE DOUBLE THROW (SPDT) SWITCH OF WIRELESS DATA COMMUNICATIONS

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DESIGN AND DEVELOPMENT OF A SINGLE POLE DOUBLE THROW (SPDT) SWITCH FOR WIRELESS DATA COMMUNICATION

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The Report Is Submitted in Partial fulfillment Of Requirements for the Bachelor Degree of Electronic & Computer Engineering (Wireless Communication) With Honours

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ABSTRACT

This project is purpose to create a suitable Single Pole Double Throw (SPDT) switch for wireless data communication and by developing process, come out with fabrication into a micro-strip circuit board and then uses network analyzer to do the measurement. Firstly, specification is set in this project which is the switch has insertion loss, isolation, return loss and frequency range. A switch in wireless communications is an electrical component that can cut off an electrical circuit, interrupting the current from one conductor to another. In this project field, an ideal switch for electronics engineering will fall short due to it have resistance, limits on the current and voltage as they can handle. A SPDT switch is a two way of switch that can change over to two terminals output in such a way that a switch can be used to switch on a red lamp in one position of a green lamp in other position just like traffic lamp. Or another word is it can act as a transceiver which can transmit and receive signal. Besides that, in this project has three different type of design topology or configuration that considers comparing the results in terms of low insertion loss and high isolation. The circuit topology has many types, but in this project only compares three types of configuration which is series, shunt-shunt-shunt and series-shunt-shunt. After the comparison made, comes out the lowest insertion loss and the highest isolation topology that will be chosen and the layout drawing process can proceed. After that, fabricate it onto a micro-strip (FR4) circuit board and observe the results using network analyzer to find the insertion loss and isolation in specification frequency 2.4GHz.

ABSTRAK

Tujuan projek ini adalah untuk mewujudkan Satu Kutub Dua Arah (SPDT) suis yang sesuai untuk kegunaan data komunikasi tanpa wayar dan melalui proses pembangunan, disertai dengan fabrikasi ke atas papan litar jalur-mikro dan kemudian mengunakan penganalisis rangkaian (*network analyzer*) untuk melakukan pengukuran. Langkah yang pertama dalam projek ini adalah menentukan spesifikasi yang perlu digunakan iaitu *insertion loss*, *isolation*, *return loss* and *frequency range*. Suis dalam sistem komunikasi tanpa wayar merupakan komponen elektrik yang boleh memutuskan pengaliran arus elektrik dalam sesebuah litar dengan mengganggu arus pengaliran arus dari satu pengalir kepada yang lain. Dalam projek ini, suis yang sempurna biasanya akan *fall short* disebabkan terdapat rintangan dan had ke atas arus dan voltan yang boleh dikawal atau dikendalikan. Suis SPDT adalah cara dua suis yang boleh bertukar kepada dua terminal keluaran. Atau perkataan lain adalah ia boleh bertindak sebagai penerima (*transceiver*) yang boleh menghantar dan menerima isyarat. Selain itu, dalam projek ini mempunyai tiga jenis reka bentuk yang berlainan topologi atau konfigurasi yang membandingkan keputusan dari segi kehilangan sisipan rendah dan pengasingan yang tinggi. Litar topologi mempunyai banyak jenis tetapi dalam projek ini hanya membandingkan tiga jenis konfigurasi yang mana satu siri, pirau-pirau-pirau dan siri-pirau-pirau. Selepas perbanding yang dibuat, pilih yang terbaik dalam keputusan kehilangan sisipan terendah dan pengasingan tertinggi dan boleh sambung susun atur proses lukisan untuk projek ini. Selepas itu, fabrikasi ke atas papan litar jalur-mikro (*FR4*) dilakukan dan hasil yang diperoleh dianalisis dengan menggunakan penganalisis rangkaian untuk mencari *insertion loss* dan *isolation* dalam specifikasi frekuensi 2.4GHz.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

SPDT	-	Single Pole Double Throw
WiMAX	-	Worldwide Interoperability for Microwave Access
RF	-	Radio Frequency
LTE	-	Long Term Evolution
Tx	-	Transmit
Rx	-	Receive
Hz	-	Hertz
GaAs	-	Gallium Arsenide
MESFET	-	Metal Semiconductor Field Effect Transistor
PLL	-	Phase-Locked Loop
FET	-	Field Effect Transistor
PIN	-	P-type Intrinsic N-type
DC	-	Direct Current
ADS	-	Advanced Design System
PCB	-	Printed Circuit Board
VSWR	-	Voltage Standing-Wave Ratio
IC	-	Integrated Circuits
TTL	-	Transistor-Transistor Logic
LP	-	Package Inductance
CP	-	Package Capacitance
CJ	-	Junction Capacitance
RP	-	Parallel Resistance
dB	-	Decibel
Vct	-	Virtual-Cut-Through

CHAPTER 1

INTRODUCTION

1.1 Overview

Nowadays, microwave switches are commonly used as control elements in some of the applications so called microsystems because of the flow of energy from the radiofrequency (RF) signal that can controlled and leaded by them from a part of the circuit to another through an external control signals. A switch in its high impedance state is characterized by the isolation it exhibits between its terminals. The isolation level is very important in every application, so that the switch must be able to preserve the transmission of RF signal power reception circuit sensitivity. Generally, the switch can be manually operated. However in many applications that use microwave integrated circuits requirements cannot be achieved manually in switching time, consequently electronic control desire to use [1].

Next, the Single Pole Double Throw (SPDT) switches are part of many microwave systems also such as transceivers, where they are used to switch a device mode of the transmitter and receiver, and the diversity of applications between the receiver front-end parts. Switch design employing SPDT Tx and Rx configuration is shown in Figure 1.1. Besides that in the transceiver, the antenna plays an important role in transmitting and receiving the 30GHz frequency band signal which is at high state. In order to control the operation of the transceiver, SPDT switch is used in switching the signal paths, either at transmission side or reception side [2].

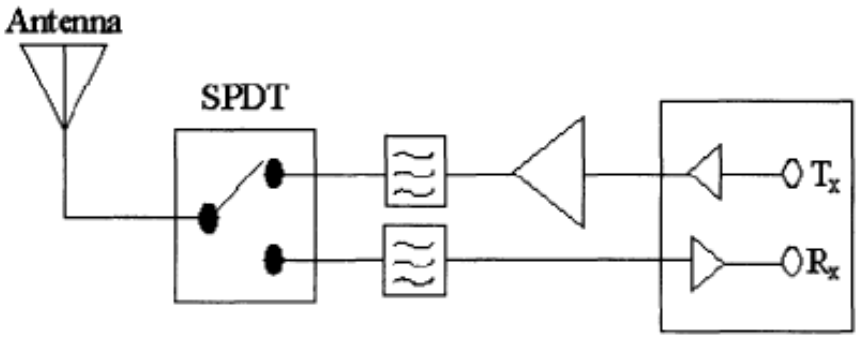

Figure 1.1 System architecture for the transceiver [2]

In addition, inside the RF/Microwave circuits switching elements that are using semiconductor diode is based on the forward and backward bias impedance characteristics. Under forward biasing interface, the diode appears as very small impedance (Rs) and under reverse bias (backward), the diode act as very large impedance (Xc) at low frequencies on microwave standard. PIN diode switches rely on a difference in power reflection, rather than power dissipation, in order to perform the switching function Semiconductor diode switches rely on a difference in power reflection, rather than power dissipation, to obtain switch performance [3].

Besides that, a microwave PIN diode is a semiconductor diode that acts as a current controlled variable resistor and can operates at RF/Microwave frequencies. If the forward bias current is varied continuously, the RF signal amplitude is modulated or attenuated. When the control current is switched on and off, the PIN diodes can be used for switching, pulse modulation, or phase shifting of the RF signal. We are concerned here only with the switching function [4].

Different circuit configuration will have own effect to the low impedance and the high impedance diode states in such a way that it can reflect RF power in a 50W line. Since the low and high impedance diode states reflect power in a 50 line, it means the basic PIN diode switch is reflective. If the PIN diode switches matched it will structure to provide a separate path for the reflected power (usually absorbed in a termination) so the signal source does not see the reflected power. Because of this purpose, the circulators and hybrid circuits are used [4].

PIN diodes are current driven devices. When forward and reverse bias switch driver supplies are selected, this must be considered. In the forward bias state, the bias supply must be able to deliver/provide 5mA, 10mA or more, from a very high impedance current source. DC induced charge was caused by this bias current and it's stored in the diode's I-region causing the diode to exhibit low impedance to the RF circuit. When the reverse bias is applied to the PIN diode, the diode is turned off (non-conducting, high impedance state). However, the diode is not really off (high impedance) until all the stored charge is removed from the I-region. Therefore, the reverse bias supply must exhibit low enough impedance to the diode that the stored charge can flow quickly to ground [4].

1.2 Problem Statement

Transmission range in a wireless data communication system is determined by transmission power output, antenna gain, receiver sensitivity and path loss. It is very simple to boost the output power and employ high-gain antennas in order to acquire the desired range. This project problem is the RF switch is widely used in wireless data communications application at nowadays and many applications require compact size, portability, low power consumption and low cost. Low power consumption can be maintained in a wireless data communication system. Besides that, it is critical to wireless data communications, to be advised this project will create a switches with a proper PIN diode that can perform a good results in terms of insertion loss and isolation. The purpose of creating a series SPDT switch is to enable the specified device can operate at 2.4GHz frequency which is around 2.3-2.7GHz of range. Different topology in circuit implementation will give a different characteristic of the switch before that many types of circuit will be designed and then simulated it. Compare the results and select the best performance of low insertion loss and high isolation and then do for fabrication and measurement procedure as switches using network analyzer to measure the losses and isolation.

1.3 Objectives

Aim of this project is to design and simulate a suitable SPDT switch topology which can operate in a specific frequency 2.4GHz and to develop the SPDT switch in the layout and fabricate it onto a micro-strip printed circuit board and improve the performance for the wireless data communications.

1.4 Scope

The scope of this project focus on the specification, topology circuit for switch, insertion loss, return loss and isolation for the SPDT connection and also the best result will be chosen. A low insertion loss and 10dB of return loss and the isolation must more than 12dB is required over a wide frequency range. Besides that, it also must understand the basic knowledge of RF switch for wireless data communications and the characteristics of PIN diodes as a suitable switch of a series SPDT switch. After this, PIN diode modeling by surveying a suitable PIN diode (HSMP-386z) from different company website modeling and then comparison which one is suite for this project in order to meet the requirements to improve the switch performance which is low insertion loss and high isolation. Simple calculation for insertion loss and isolation is the next step and then, ADS software is important for this project in order to do the simulation and need analyze the selected switch by comparing three different type of circuit topology using single biasing configuration. After that, draw the RF switch layout in ADS software and then fabricate it onto a FR4 board (etching process). Lastly, test the prototype by using network analyzer.

1.5 Report Structure

This report contains six chapters which are introduction, literature review, methodology, results, discussion and conclusion. Firstly, **CHAPTER 1** is introduction which it will briefly describe about the background and overview of this project. Besides that, this chapter covers problems statement, objectives, scope of the project, expected outcome and methodology.

Next, **CHAPTER 2** contains the literature review or research to get information about this project. In order to get the information which is related, there will have many resources can gained from it such as internet, journals, books and etc. Those facts and information that can found from the resources and will then compared to search for the best method and techniques that can implemented in this project.

For **CHAPTER 3**, mainly focuses on the methodology which used in this project such as data acquisition module, pre-processing module, standardized module, classification modules, and decision-making module. Follow this methodology; it will get a better performance.

In **CHAPTER 4**, results will be observed and analysis and measurement are done for this project. This chapter will covers the simulation results by using proper software and then compared with different topology and figure out the best choice of result that meet the requirement. Besides that, this part also doing the testing for several times. The purpose of test, expected results, procedures, discussion, and conclusion for each test will be detailed out is this chapter. All testing results are attached with the proper aid of figure and table. For discussion part, it will discuss the results based on the observation, analysis, and measurement do testing. Table is important in this part in order to simplify it and easy to analysis and make a discussion. Percentage is the part for compared the measured, simulation and calculation.

Lastly, conclusion is done at **CHAPTER 5**. This chapter will conclude the whole procedures of the project that including project finding, achievement analysis and conclusion of the research implementation that had been used. If necessary, this chapter can discuss about the suggestion for enhancement.

1.6 Methodology

The procedure will be done by study or literature review about the SPDT switching, RF switching and PIN diode. Next is to design the switch with 3 different types of topology switch and then simulate by using ADS software to get the comparison of circuit topologies within a certain range of frequency. Then draw the layout for the circuit and print it. After that do lamination for this project circuit using ADS and fabrication will do which consists of etching and others step and then soldering will do it by purchasing a suitable PIN diode and others components into the FR4 board. Finally, test the switch using network analyzer at 2.3 to 2.7GHz frequency range.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature study or literature review is important for a project due to any essential information that relevant to the project can refer to this chapter. By collecting information from resources and the knowledge, it can easily do the project by understanding the concept of the title about the functionality. This chapter will cover all the information that is relevant to this project.

2.2 RF Switching

With the recent surge in the development of RF switch test system availability of products for your application to choose the right products have become increasingly difficult. Most RF manufacturers introduced their RF switching products using two main specifications which is the topology and bandwidth (such as the NI PXI-2594 2.5 GHz 4x1 multiplexer). Next is to introduce the seven important specifications that must be considered when designing RF switch network as shown as below [5]:

Characteristic impedance:

- Bandwidth
- Topology
- Insertion Loss
- Return loss and voltage standing-wave ratio (VSWR)
- Isolation and crosstalk
- Rise time

In the discussion of the characteristic impedance and other RF switch specifications, it is first important to understand the difference between understanding the signal propagation in DC circuits versus RF systems. In the DC circuits or circuits in a low-frequency signal transmission, the voltage of the signal at different points on a cable in the signal path is varies minimally. Consider two waves (signals) with different frequencies through a 1 m coaxial cable transmission case [5].

2.3 Switch Parameter

Usually the fabricated switch circuits do not have ideal performance due to of its finite impedance of the impedance of the switching devices and finite losses of the connecting circuitry. If want to have a perfect performance of a practical switch can be expressed by specifying its insertion loss and isolation as the basic design parameters.

Frequency range

- RF and microwave applications at a frequency range from 100 MHz for semiconductor to 60 GHz for satellite communications. Expansion of frequency range of broadband accessories is to increase the flexibility of the test system. However, the frequency is always dependent on a wide range of applications and the operating frequency may be sacrificed to meet the other critical parameters.