DESIGN AND ANALYSIS OF SELECTABLE MULTIBAND ISOLATION USING SINGLE SWITCHABLE RESONATOR FOR RF SWITCH APPLICATION

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Supervisor Name	:	DR NOOR AZWAN BIN SHAIRI
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DEDICATION

For my family, my supervisor, Dr Noor Azwan Bin Shairi and all my friends.

ABSTRACT

In many wireless communication applications, it is necessary to switch the RF signal path to route and connect to different antennas, amplifiers, and filters. The multiband RF front-end is developed to support several RF front-end systems. High isolation between transmitter and receiver in the RF front-end is one of the key parameters in RF switch design. However, the major concern for multiband isolation switch is increasing of the total current consumption and overall circuit size. In order to achieve a high isolation and at the same time miniature circuit, this project proposes selectable multiband isolation using single switchable resonator in Single Pole Double Throw Switch (SPDT) Switch. The SPDT switches were designed in 2.3 GHz and 3.5 GHz bands. The design involves simulation using ADS software and fabricated using FR4 board. Measurement is necessary for verification with simulation results. As a result, the simulated and measured results showed the return loss is greater than 10dB, insertion loss is less than 3dB and isolation value is higher than 25dB in 2.3 GHz and 3.5 GHz bands. The proposed design is suitable for high power applications with 1 Watt and 10 Watt transmits output.

ABSTRAK

Kebanyakan aplikasi komunikasi wayarles perlu menukar isyarat RF dan menyambung ke antena, penguat, dan penapis yang berbeza. Perkembangan multiband RF sistem adalah untuk menyokong beberapa sistem front-end RF. Pengasingan yang tinggi antara pemancar dan penerima adalah parameter utama dalam reka bentuk suis RF. Namun, kebimbangan utama bagi suis pengasingan multiband adalah peningkatan jumlah penggunaan semasa dan saiz litar keseluruhan. Untuk mencapai pengasingan yang tinggi dan memperkecilkan litar, projek ini mencadangkan pengasingan multiband yang boleh dipilih dengan menggunakan resonator switchable dalam Switch Single Pole Double Throw (SPDT). Suis SPDT direka dalam 2.3 GHz dan 3.5 GHz band. Reka bentuk ini melibatkan simulasi menggunakan perisian ADS dan direka menggunakan papan FR4. Pengukuran diperlukan untuk pengesahan dengan keputusan simulasi. Akibatnya, keputusan simulasi dan diukur menunjukkan kurang daripada 3dB kehilangan sisipan, lebih besar daripada 10dB kehilangan pulangan dan lebih tinggi daripada 25dB pengasingan 2.3 GHz dan 3.5 GHz band. Reka bentuk yang dicadangkan sesuai untuk aplikasi kuasa tinggi dengan 1Watt dan 10Watt menghantar output.

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LIST OF SYMBOLS AND ABBREVIATIONS

SPDT	:	Single Pole Double Throw
RF	:	Radio Frequency
ADS	:	Advanced Design Software
TDD	:	Time-Division Duplexing
MEMS	:	Micro Electromechanical Systems
PCB	:	Printed Circuit Boards

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CHAPTER 1

INTRODUCTION

1.1 Background of Project

Single Pole Double Throw switch (SPDT) is one type of the radio frequency (RF) switch as shown in Figure 1. It is used to switch signals between transmitting and receiving process to perform time division duplex (TDD) in RF front-end system such as WiFi, WiMAX and LTE[1]. High isolation value between the transmitter and receiver in the RF front end system is an important parameter in the design SPDT switch, especially for high power applications.

For SPDT switch, PIN diodes or FETs acts as the switching elements. The PIN diode is a semiconductor used for various devices such as RF and microwave applications. It has a unique variable resistance characteristic by utilizing small amount of voltage and current to control RF signal. However, power handling capability of MEMs switches is limited which make it not suitable integrated in RF and microwave applications which required high power[2]. In addition, PIN diode switch is more reliable compared to MEMs switches and widely used due to its fast switching speed, long lifespan and suitable for high-power applications.

Isolation is one of the key parameters that should take in consideration when selecting an RF. It is defined as the ratio of the power level when the switch is in OFF state to the power level when the switch is in ON state. For a good isolation performance, it can prevent stray signals from leaking into the desired signal path. To achieve high isolation is critical in measurement systems where signals can be routed consistently from a variety of sources and to receivers through various switch test ports [3]. Hence, circuit design, resonant circuit and materials used for fabrication should take in consideration to improve the isolation performance. However, the PIN diode make the circuit design discrete and difficult to obtain high isolation which is larger than 20dB. There is a trade-off in high isolation techniques which are increasing the overall circuit size, higher number of PIN diodes, and limited choice of lumped component value [4].

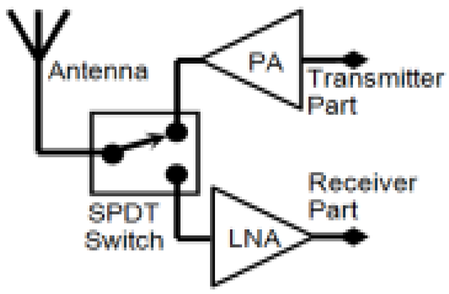

Figure 1.1 :**Application of SPDT in RF Front End System**

In modern wireless communication, there is a demand on the RF switch in wireless communication service and it is expected to have high potential marketability especially in high-frequency product developments. In WiMAX systems where PIN diodes provide the required performance for WiMAX base-station applications, handling higher power signals with low insertion loss, fast switching speed and high isolation performance need to be addressed[5]. Figure 1 shows an example of SPDT switch required to support two different frequency bands in RF applications. Therefore, the multiband RF systems is required to be integrated for different standards such as WiFi and WiMAX or different spectrum allocations at various locations. Hence, it is necessary to propose a selectable multiband isolation and compact size of RF switch.

1.2 Problem Statement

Until now, discrete PIN diodes are still highly desire for high power applications such as in military, satellite communication and base station. In order to increase isolation of SPDT switch, there are several techniques used. Combination of series and shunt configuration are the most widely used technique. However, the major concern of this technique is increasing overall circuit size. Hence, in this project, the method of miniature the circuit by combining two resonators in a single resonator has been proposed in order to reduce the circuit size and get high isolation at 2.3 GHz and 3.5 GHz bands for multiband isolation SPDT switches to support RF switch applications.

1.3 Objectives

1. To design a selectable multiband isolation using single switchable resonator for RF switch application at 2.3GHz and 3.5GHz bands.
2. To analyse the performance of multiband isolation at 2.3GHz and 3.5GHz.
3. To fabricate and measure the designed SPDT switches in order to validate the simulation results.

1.4 Scope of Project

This project is to design selectable multiband isolation using Single Switchable Resonator for RF Switch Application based on microstrip line model using Advance Design System (ADS) software 2011. The S-parameters of the switch are analysed in the ADS software in terms of isolation, insertion loss and return loss. The circuit of the switch is designed as layout in ADS in order to be prepared for fabrication. The designed circuit is fabricated to validate the performance of the multiband isolation SPDT and switches. In the fabrication, substrate material of (FR4), standard packaged of PIN diodes BAP64-02 (NXP Semiconductors), inductors and capacitors are used. The measurement is done to validate the performance results of SPDT switch return loss (S_{11}), insertion loss (S_{12}) and isolation (S_{13}). This project covers for SPDT switch and the multiband isolation only in two different frequencies in 2.3GHz and 3.5GHz.

1.5 Significant of Project

In this project, the design multiband isolation SPDT switch using single switchable resonators for RF switch application at 2.3 GHz and 3.5 GHz bands will generates high isolation. The switch circuit size is designed combining two resonators into a single resonator which become more compact and this will lead to less materials used where low cost and low power consumption are essential requirements in wireless communication systems. In addition, it could still maintain high power capability in smaller size with low resistance and high reliability that can be integrated at base stations and can be used to support WiMAX and LTE applications.

Furthermore, FR4 board material are widely used in electronics applications since it is more reliable and low cost. An isothermal ageing of printed circuit board materials is presented under high temperature (190 degree), it is found that FR4 can nonetheless be used over long periods of time (1000h)[6]. Unlike CEM-1, although it is cheaper than FR-4 but its mechanical characteristics are worse than FR-4. Besides, CEM-1 is more fragile. Therefore, FR4 boards with suitable price and long lifespan is an important consideration as it will bring effect to environment indirectly.

RF-Switches can also be used for Rx/Tx switching and band selecting. The potential application of multiband isolation SPDT switch at 2.3 GHz and 3.5 GHz is for communication system such as mobile phones, Bluetooth accessories, WiMAX and GPS navigation systems. This project covered a small area of RF switch simulation and optimization. Given the ever-growing nature of the cellular industry, the potential opportunities to advance our modelling environment will only grow.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

In the microwave and milli-meter wave communication systems, SPDT switches are commonly used in signal routing for transmit and receive operation, wideband tuning networks and switched-line phase shifter in phased array antenna. Generally, GaAs MESFETs and PIN diodes are integrated in the SPDT switches, however the performance of GaAs FET in switching circuits are affected due to their high insertion value and low isolation value in high frequency range when compared to the performance of microelectromechanical systems (MEMS) switches even though they show good performances at low frequencies[7]. In addition, the nonlinear characteristics result in higher power consumption and significant intermodulation.

Hence, the recently developed RF switches and MEMS switches are used as an alternative since they are receiving attentions due to their performances which are high isolation, low insertion loss, negligible power consumptions and good linearity[8]. By using MEMS technology, SPDT switches were implemented instead of using the conventional solid-state switches.

SPDT switch is fundamental switch to support a wide range of systems. Since RF switches has very high demand for different bands; wide, broad and multi-band RF front-end in wireless communication systems such as WiFi, WiMAX, LTE, WiBro, HiperLAN. To make RF front end cheaper, smaller and more valuable, subcomponent should be eliminated so that the size of RF switch will reduce.

In this chapter, the theory of RF switch, operation, configuration and parameters of RF switches is introduced. Then, followed by discussing the research work on single, wide and multiband RF switch.

2.2 Time Division Duplexing

The simplest case of multiple access is the problem of two ways transceiver communication, a feature called “duplexing”. In old walkie-talkies, for example the user would press the “talk” button to transmit while disabling the receive path and release the button to listen while disabling the transmit path. This can be considered a simple form of time-division duplexing (TDD) whereby the same frequency band is used for the transmit (TX) and receive (RX) paths, but the system transmits half time and receives the other half [9]. As illustrated in Figure 2.1, TDD is usually performed fast enough to be transparent to the user.