Faculty of Electronic and Computer Engineering

DESIGN AND ANALYSIS OF MULTIBAND ISOLATION RF SWITCH USING TRANSMISSION LINE STUB RESONATORS FOR WIMAX AND LTE APPLICATIONS

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Master of Science in Electronic Engineering

2016

DESIGN AND ANALYSIS OF MULTIBAND ISOLATION RF SWITCH USING TRANSMISSION LINE STUB RESONATORS FOR WIMAX AND LTE APPLICATIONS

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**A thesis submitted
in fulfillment of the requirements for the degree of Master of
Science in Electronic Engineering**

Faculty of Electronic and Computer Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this thesis entitle "Design and Analysis of Multiband Isolation RF Switch Using Transmission Line Stub Resonators for WiMAX and LTE Applications" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:…………………………………………………...
Name	: Abdullah Mohammed Saghir Zobilah
Date	:…………………………………………………..

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electronic Engineering.

Signature :……………………………………………………….

Supervisor Name : PM Dr. Zahriladha Bin Zakaria

Date :……………………………………………………….

DEDICATION

To my beloved mother and father

ABSTRACT

In the area of multiband wireless communications, the development of multiband RF front-end sub-components (e.g. amplifiers, filters, switches and antennas) are highly desired, and they were 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, especially for high power applications such as base stations and wireless infrastructure. High isolation between the RF front-end's transmitter and receiver is required to minimize any high RF power leakage that could distort active circuits in the receiver, especially the low-noise amplifiers. Hence, this research proposes a multiband isolation RF switch as (Single Pole Double Throw (SPDT) and Double Pole Double Throw (DPDT)) design using switchable transmission line stub resonators for applications of Worldwide Interoperability for Microwave Access (WiMAX) and Long-Term Evolution (LTE) in 2.3 and 3.5 GHz bands. Clearly, a multiband isolation discrete RF switch was designed in two ways, fixed and selectable. The transmission line stub resonator used in this research work is an open stub resonator with quarter wave of the electrical length. The theory of the stub resonator is discussed using a simple mathematical model where it can be cascaded and resonated at 2.3 and 3.5 GHz. Moreover, the cascaded transmission line stub resonators can be reconfigured between allpass and bandstop responses using discrete PIN diodes. The key advantage of the proposed SPDT and DPDT with switchable transmission line stub resonators is a high isolation with minimum number of PIN diodes. As a result, the simulated and measured results showed less than 3 dB of insertion loss, greater than 10 dB of return loss and higher than 30 dB of isolation in 2.3 GHz and 3.5 GHz bands. Thus, the proposed design is suitable for high power applications with 1 Watt and 10 Watt transmits output. In addition, the selectable SPDT and DPDT switch show the best performance as they are able to operate with different frequencies using single hardware and thus, overcoming the interference issue.

ABSTRAK

Dalam bidang pelbagai jalur komunikasi wayarles, pembangunan sub bahagian depan RF komponen pelbagai jalur (misalnya penguat, turas, suis dan antena) mempunyai permintaan tinggi, dan peranti ini dibangunkan bagi menyokong beberapa sistem bahagian depan RF. Pengasingan tinggi antara pemancar dan penerima dalam bahagian depan RF ialah salah satu parameter yang penting dalam reka bentuk suis RF, terutamanya bagi aplikasi-aplikasi berkuasa tinggi seperti stesen pangkalan dan prasarana wayarles. Pengasingan tinggi antara pemancar dan penerima bahagian depan RF diperlukan untuk meminimumkan mana-mana kebocoran kuasa RF yang boleh mengubah bentuk litar aktif dalam penerima, terutamanya penguat hingar rendah. Maka, penyelidikan ini mencadangkan suis RF pengasingan pelbagai jalur sebagai (Single Pole Double Throw (SPDT) dan Double Pole Double Throw (DPDT)) reka bentuk yang menggunakan suis alat resonans puntung talian penghantaran untuk aplikasi Worldwide Interoperability for Microwave Access (WiMAX) dan Long-Term Evolution (LTE) dalam jalur 2.3 dan 3.5 GHz. Jelas sekali bahawa pengasingan pelbagai jalur suis RF diskret telah direka bentuk dalam dua hala, bersifat kekal dan bersifat boleh dipilih. Alat resonans puntung talian penghantaran yang digunakan dalam kerja penyelidikan ini ialah alat resonans puntung terbuka dengan gelombang sukuan panjang elektrik. Teori alat resonans puntung diperbincangkan menggunakan sebuah model matematik mudah di mana ia boleh diturunkan dan bergema di 2.3 dan 3.5 GHz. Tambahan pula, puntung talian penghantaran melata alat resonan boleh dikonfigurasi semula antara tindak balas semua hantaran dan jalur batas menggunakan diod PIN yang diskret. Kelebihan utama SPDT and DPDT yang telah dicadangkan dengan suis puntung talian penghantaran alat resonan ialah pengasingan tinggi dengan bilangan minima PIN diod. Hasilnya, keputusan hasil simulasi dan eksperimen menunjukkan kehilangan sisipan kurang daripada 3 dB, kehilangan balikan lebih besar daripada 10 dB dan pengasingan lebih tinggi daripada 30 dB dalam jalur 2.3 GHz dan 3.5 GHz. Oleh hal yang demikian, cadangan reka bentuk ini adalah sesuai untuk aplikasi-aplikasi kuasa tinggi dengan 1 Watt dan 10 Watt menghantar keluar. Selain itu, suis bersifat boleh pilih SPDT and DPDT menunjukkan prestasi terbaik kerana ia mampu beroperasi dengan frekuensi-frekuensi berbeza menggunakan perkakasan tunggal dan sekaligus dapat mengatasi isu gangguan semasa.

ACKNOWLEDGMENTS

I would like to thank my supervisor PM Dr. Zahriladha Bin Zakaria from Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement to accomplish this thesis.

I would also like to thank my co-supervisor Dr. Noor Azwan Shairi for his advices, recommendations and suggestions throughout this project. The door to Dr. Azwan was always open whenever I had a question about my research or writing. He steered me in the right direction whenever he thought I needed it.

Thanks to all my colleagues, my beloved mother, father and siblings for their moral support in completing this degree. Finally, thanks to everyone who motivated me to finish up my project.

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LIST OF ABBREVIATION

ADS	-	Advanced Design System
CMOS	-	Complementary Metal Oxide Semiconductor
DC	-	Direct Current
DPDT	-	Double Pole Double Throw
FET	-	Field-Effect Transistors
FR4	-	Flame Retardant 4
GaAs	-	Gallium Arsenide
LNA	-	low noise amplifier
LTE	-	Long Term Evolution
MEMs	-	Micro Electro Mechanicals
MMIC	-	Monolithic Microwave Integrated Circuit
MIMO	-	Multi-input Multi-output
PCB	-	Printed Circuit Board
pHEMT	-	Pseudomorphic High Electron Mobility Transistor
RF	-	Radio Frequency
SiGe	-	Silicon Germanium
SPDT	-	Single Pole Double Throw
SPST	-	Single Pole Single Throw
T/R	-	Transmit and Receive
TDD	-	Time Division Duplex
WiFi	-	Wireless Fidelity
WiMAX	-	Worldwide Interoperability for Microwave Access

LIST OF APPENDICES

LIST OF PUBLICATIONS

Journals:

1. A. M. S. Zobilah, N. A. Shairi, Z. Zakaria, and M.S. Jawad, 2016. "RF switches in wide- , broad- , and multi-band RF front-end of wireless communications : An overview," *ARPN journal of engineering and applied sciences (JEAS)*, 11, pp.3244–3248.

2. A. M. Zobilah, N. A. Shairi, and Z. Zakaria."Selectable Multiband Isolation Single Pole Double Throw Switch Using Transmission Line Stub Resonator for WiMAX and LTE Applications,*" IET Microwaves, Antennas & Propagation* (Accepted).

3. A. M. Zobilah, N. A. Shairi, and Z. Zakaria."Fixed and Selectable Multiband Isolation Double Pole Double Throw Switch Using Transmission Line Stub Resonators for WiMAX and LTE,*" Progress In Electromagnetics Research B,* 72, pp.95-110.

Conference:

1. A. M. Zobilah, N. A. Shairi, and Z. Zakaria. "Multiband Isolation of DPDT Switch with Switchable Transmission Line Stub Resonators for WiMAX and LTE in 2.3 and 3.5 GHz Bands," *The 3rd International Conference on Electronic Design (ICED) 2016.*

AWARDS

1. Best Paper Award: Multiband Isolation of DPDT Switch with Switchable Transmission Line Stub Resonators for WiMAX and LTE in 2.3 and 3.5 GHz Bands. *The 3rd International Conference on Electronic Design (ICED),* 2016.

2. Silver Medal: Multiband Isolation of DPDT Switch with Switchable Transmission Line Stub Resonators for WiMAX and LTE in 2.3 and 3.5 GHz Bands. *Mini UTeMX*, 2016.

CHAPTER 1

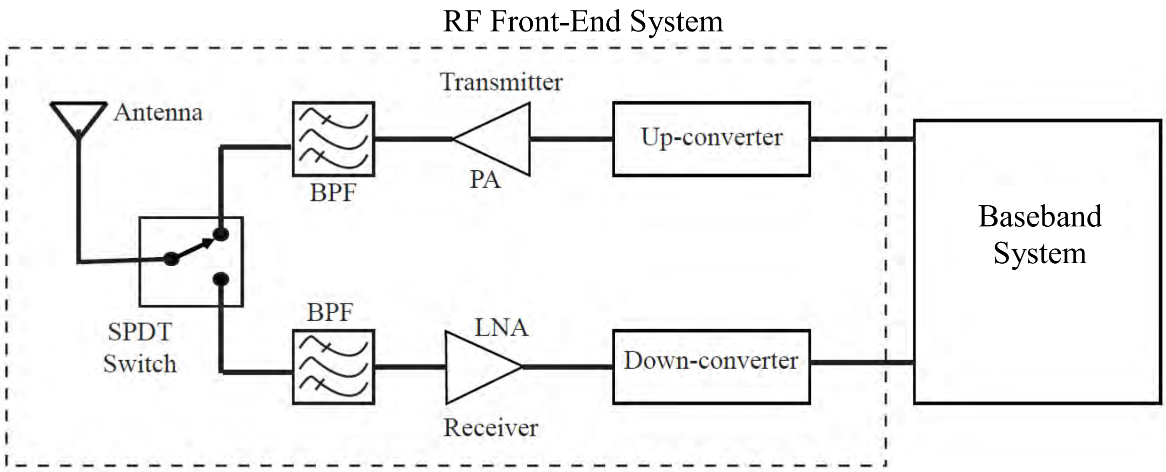
INTRODUCTION

1.1 Research Background

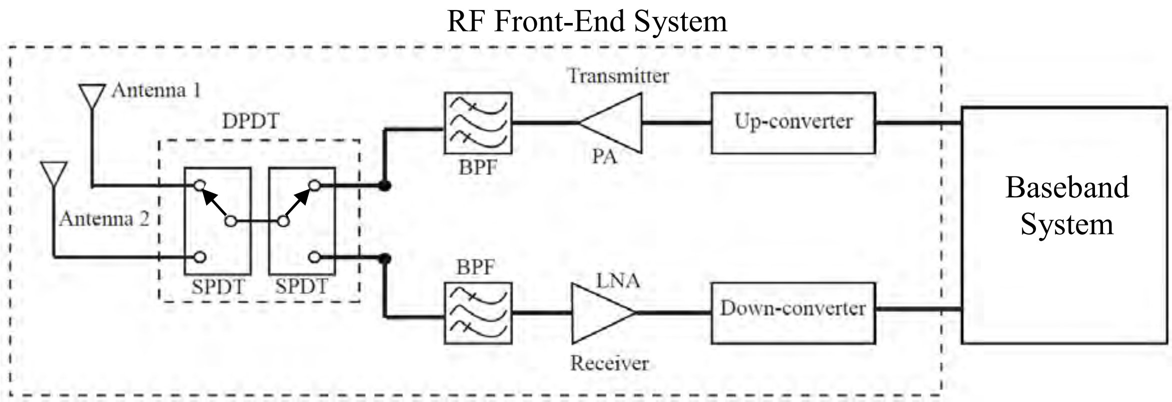
Radio frequency (RF) and microwave switches are generally used for signal routing between transmitter and receiver. RF switches could be executed in such civilian wireless communication systems, where they are aimed for mass production, and for other systems, where they are manufactured in small quantities (Berezniak & Korotkov 2013). Examples of civilian wireless communication systems for data exchange in different standards are Time Division Synchronous Code Division Multiple-Access (TD-SCDMA), Wireless Fidelity (WiFi), Worldwide Interoperability for Microwave Access (WiMAX), and other applications.

RF switches or commonly known as Double Pole Double Throw (DPDT) switch and Single Pole Double Throw (SPDT) switch are widely used in wireless communication systems to switch signals from antennas to transmitter and receiver paths (Hindle 2010). In another word, their function is supporting Time Division Duplex (TDD) for switching between uplink (transmitter, Tx) and downlink (receiver, Rx) in such WiMAX and Long-Term Evolution (LTE) applications.

High isolation between transmitter part and receiver part plays an important role in multiband isolation SPSDT switch and DPDT switch due to its ability to reduce RF power leakage from part to the other (Gothch 2007). This leakage should be solved in order to avoid distorting the active circuits in RF front-end like low noise amplifiers. Hence, series-shunt discrete PIN diodes are the best Switch configuration especially for high power applications of wireless communication such as that used in based stations (BS), military and satellite communication (Hindle 2010; A.F. Berezniak & Korotkov 2013). Figure 1.1 shows RF front-end system with SPDT and DPDT switches.



(a)



(b)

Figure 1.1: RF front-end system with (a) SPDT switch (b) DPDT switch (Hsu et al. 2007)

Moreover, in modern wireless communication, there is a requirement of designing a wide-, broad- or multi-band RF front-end. It requires wide-, broad- or multi-band RF subcomponents in the RF front-end to support different bands and different standards (e.g. WiFi, WiMAX, LTE and etc.). Therefore, these have created new challenges to circuit and system designers in developing a wide-, broad- or multi-band RF front-end system. Several wide-, broad- or multi-band RF subcomponents can be found in antenna (Malek et al. 2013), filter (Zakaria et al. 2015) and amplifier designs (Ho et al. 2014).

Therefore, in this study, multiband isolation SPDT switch and multiband isolation DPDT switch using transmission line stub resonators for WiMAX and LTE applications in 2.3 GHz and 3.5 GHz are proposed. These applications require greater than 25 dB of isolation in order to reduce RF power leakage between transmitter and receiver. Besides that, the use of transmission line stub resonators will help to use minimum number of PIN diodes in the design.

1.2 Problem Statement

High isolation between transmitter and receiver in the RF front-end is one of the key parameters in RF switch design. High isolation is required, between the RF front-end's transmitter and receiver, to minimize any high RF power leakage that could distort active circuits in the receiver, especially the low noise amplifiers (Gothch 2007).

Series-shunt switch design is the better choice for high power application like wireless infrastructure or base station (Bukowski 2007). However, it is difficult to obtain high isolation if only discrete PIN diodes are used (Semiconductors 2015). In general, according to (Hu et al. 2011), more than 25 dB of isolation of RF switch is required for high power application to attenuate high RF power leakage between a transmitter and a receiver in the RF front-end system.

From literature study, there are four techniques that can be used to obtain high isolation in SPDT switch design. However, for the solution of discrete circuit design using standard discrete PIN diode packages, there are trade-offs in these high isolation techniques such as increasing the overall circuit size, higher number of PIN diodes, and limited choice of lumped component values (Abdul Hadi et al. 2014). On the other hand,