



**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**

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

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

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**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 resonans 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 resonans 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.*

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## TABLE OF CONTENTS

	<b>PAGE</b>
<b>DECLARATION</b>	<b>i</b>
<b>APPROVAL</b>	<b>ii</b>
<b>DEDICATION</b>	<b>iii</b>
<b>ABSTRACT</b>	<b>i</b>
<b>ACKNOWLEDGMENTS</b>	<b>iii</b>
<b>TABLE OF CONTENTS</b>	<b>iv</b>
<b>LIST OF TABLES</b>	<b>vii</b>
<b>LIST OF FIGURES</b>	<b>ix</b>
<b>LIST OF ABBREVIATION</b>	<b>xiii</b>
<b>LIST OF APPENDICES</b>	<b>xiv</b>
<b>LIST OF PUBLICATIONS</b>	<b>xv</b>
<b>AWARDS</b>	<b>xvi</b>
<b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Research Background	1
1.2 Problem Statement	3
1.3 Objectives	4
1.4 Scope of Research	4
1.5 Contribution of Research Work	5
1.6 Thesis Organization	6
<b>2. LITERATURE REVIEW</b>	<b>8</b>
2.1 Introduction	8
2.2 Modern Wireless Communication	8
2.3 RF Front-End	9
2.4 RF Switch	11
2.4.1 RF Switch Element and Performance	11
2.4.2 Applications of RF Switch	12
2.4.3 Configurations of RF Switch	13
2.4.4 Operation of RF Switch	14
2.4.5 Relevant Parameters for RF Switch	15

2.5	Theory of Transmission Line Resonator	18
2.6	Research Works on Single Band RF Switch Design	21
2.7	Research Works on Multi and Wide Band RF Switch Design	26
2.8	Summary	34
<b>3.</b>	<b>RESEARCH METHODOLOGY</b>	<b>35</b>
3.1	Introduction	35
3.2	Methodology	35
3.3	Specifications of Multiband Isolation SPDT and DPDT Switches	36
3.4	Mathematical Modeling	38
3.4.1	Switchable Transmission Line Open Stub Resonators	38
3.4.2	Mathematical Modeling Result	41
3.4.3	SPDT and DPDT Switches with Transmission Line Stub Resonators	43
3.5	Cascaded Transmission Line Stub Resonators	44
3.6	Multiband Isolation SPDT and DPDT Switches	46
3.6.1	Multiband Isolation SPDT Switch	47
3.6.2	Multiband Isolation DPDT Switch	55
3.7	Simulation and Layout	65
3.8	Fabrication, Soldering and Measurement	66
3.9	Summary	68
<b>4.</b>	<b>RESULTS AND DISCUSSIONS</b>	<b>69</b>
4.1	Introduction	69
4.2	Parametric Study	69
4.3	Result of Multiband Isolation SPDT Switch	71
4.3.1	Result of Fixed Multiband Isolation SPDT Switch (Design 1)	71
4.3.2	Result of Selectable Multiband Isolation SPDT Switch (Design 2)	75
4.4	Result of Multiband Isolation DPDT Switch	82
4.4.1	Result of Fixed Multiband Isolation DPDT switch (Design 3)	82
4.4.2	Result of Selectable Multiband Isolation DPDT Switch (Design 4)	85
4.5	Comparison of Multiband Isolation SPDT and DPDT Switch Designs	92
4.6	Conventional SPDT and The Proposed SPDT Switch	94
4.7	Comparison between the Related Research and The Proposed Research Work	95
4.8	Summary	97
<b>5.</b>	<b>CONCLUSION AND FUTURE WORKS</b>	<b>99</b>

5.1	Conclusion	99
5.2	Suggestions for Future Works	100
	<b>REFERENCES</b>	<b>102</b>
	<b>APPENDIX A</b>	<b>116</b>
	<b>APPENDIX B</b>	<b>118</b>
	<b>APPENDIX C</b>	<b>119</b>

## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	WiMAX international frequency allocation	9
2.2	RF switch in single band application	25
2.3	Summarizations of RF switch designs in wideband, broadband and multiband applications	33
2.4	Comparison between the most related works to our proposed design	34
3.1	Multiband isolation SPDT and DPDT switches' specification	38
3.2	Summarization of the process in receiver and transmitter modes of fixed multiband isolation SPDT switch using transmission line open stub resonators for WiMAX and LTE applications	49
3.3	Summarization of the process in receiver and transmitter modes of selectable multiband isolation SPDT switch using transmission line open stub resonators for WiMAX and LTE applications	54
3.4	Summarization of the process in receiver and transmitter modes of fixed multiband isolation DPDT switch using transmission line open stub resonators for WiMAX and LTE applications	58
3.5	Summarization of the process in receiver and transmitter modes of selectable multiband isolation DPDT switch using transmission line open stub resonators for WiMAX and LTE applications	64
4.1	Summarizes resonators lengths and resonant frequency	71

4.2	Performance summary of fixed multiband isolation SPDT switch with transmission line stub resonator	74
4.3	Performance summary of selectable multiband isolation SPDT switch with transmission line stub resonators (case 1)	77
4.4	Performance summary of selectable multiband isolation SPDT switch with transmission line stub resonators (case 2)	79
4.5	Performance summary of selectable multiband isolation SPDT switch with transmission line stub resonators (case 3)	81
4.6	Performance summary of multiband isolation DPDT switch with transmission line stub resonators	84
4.7	Performance summary of selectable DPDT switch with transmission line stub resonators (case 1)	87
4.8	Performance summary of selectable Multiband Isolation DPDT switch with transmission line stub resonators (case 2)	89
4.9	Performance summary of selectable multiband isolation DPDT switch with transmission line stub resonators (case 3)	91
4.10	Summarization of the number of PIN diodes used in multiband isolation SPDT and DPDT switches for WiMAX and LTE applications at 2.3 GHz and 3.5 GHz	93
4.11	Isolation performance summarization of multiband isolation SPDT and DPDT switches for WiMAX and LTE applications	94
4.12	A comparison between this research work and conventional SPDT switch in terms of number of PIN diodes, isolation performance and circuit size	95
4.13	Comparison between the previous research works and this work	97

## LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	RF front-end system with (a) SPDT switch (b) DPDT switch	2
2.1	RF front-end for (a) TDD system (b) FDD system	10
2.2	Diagram of (a) DPDT switch (b) SPDT switch in RF-front end	13
2.3	Basic RF switch configuration, (a) series RF switch (b) shunt RF switch (c) series-shunt RF switch	14
2.4	Basic structure of microstrip	18
2.5	A transmission line terminated in a load impedance $Z_L$	18
2.6	A transmission line terminated in a short circuit	19
2.7	Impedance variation along a short circuited transmission line	19
2.8	A transmission line terminated in an open circuit	20
2.9	Impedance variation along an open circuited transmission line	20
3.1	The flow chart of the project	36
3.2	General diagram of transmission line stub resonator	38
3.3	Two-port network of series-shunt PIN diode with open stub resonators	44
3.4	Circuit diagram of switchable transmission line stub resonator. Circuit operation: (b) ON state (bandstop response) and (c) OFF state (allpass response)	45
3.5	Multiband isolation SPDT and DPDT switch designs for WiMAX	

	and LTE	46
3.6	Circuit diagram of fixed multiband isolation SPDT switch using transmission line open stub resonators	47
3.7	Circuit diagram of fixed multiband isolation SPDT switch using transmission line open stub resonators (Transmitter mode)	48
3.8	Circuit diagram of fixed multiband isolation SPDT switch using transmission line open stub resonators (Receiver mode)	49
3.9	Circuit diagram of selectable multiband isolation SPDT switch using transmission line open stub resonators	50
3.10	Circuit diagram of selectable multiband isolation SPDT switch using transmission line open stub resonators (Transmitter mode)	52
3.11	Circuit diagram of selectable multiband isolation SPDT switch using transmission line open stub resonators (Receiver mode)	53
3.12	Circuit diagram of fixed multiband isolation DPDT switch using transmission line open stub resonators	56
3.13	Circuit diagram of fixed multiband isolation DPDT switch using transmission line open stub resonators (Transmitter mode)	57
3.14	Circuit diagram of fixed multiband isolation DPDT switch using transmission line open stub resonators (Receiver mode)	58
3.15	Circuit diagram of selectable multiband isolation DPDT switch using transmission line open stub resonators	60
3.16	Circuit diagram of selectable multiband isolation DPDT switch using transmission line open stub resonators (Transmitter mode)	61
3.17	Circuit diagram of selectable multiband isolation DPDT switch using transmission line open stub resonators (Receiver mode)	63

3.18	Schematic window of ADS Software	65
3.19	(a) The layout window of ADS software. (b) The printed layout design of the multiband isolation SPDT switch	66
3.20	Soldering tools	67
3.21	Agilent network analyzer and power supply with device under test (DUT)	67
4.1	The result of resonant frequency due to changing (a) L1 (b) L2	70
4.2	Fixed multiband isolation SPDT Switch with transmission line stub resonators	72
4.3	Simulation and measurement results of fixed multiband isolation SPDT switch, (a) isolation ( $S_{13}$ ) (b) return loss ( $S_{11}$ ) (c) insertion loss ( $S_{12}$ )	74
4.4	The prototype of selectable multiband isolation SPDT switch	75
4.5	Simulation and measurement results of selectable multiband isolation SPDT switch (case 1), (a) isolation ( $S_{13}$ ) (b) return loss ( $S_{11}$ ) (c) insertion loss ( $S_{12}$ )	77
4.6	Simulation and measurement results of selectable multiband isolation SPDT switch (case 2), (a) isolation ( $S_{13}$ ) (b) return loss ( $S_{11}$ ) (c) insertion loss ( $S_{12}$ )	79
4.7	Simulation and measurement results of selectable multiband isolation SPDT switch (case 3), (a) isolation ( $S_{13}$ ) (b) return loss ( $S_{11}$ ) (c) insertion loss ( $S_{12}$ )	81
4.8	The Prototype of fixed multiband isolation DPDT switch with transmission line stub resonators	83
4.9	Simulation and measurement results of multiband isolation DPDT	84



	switch with transmission line stub resonator, (a) isolation ( $S_{12}$ ) (b) return loss ( $S_{11}$ ) (c) insertion loss ( $S_{14}$ )	
4.10	The prototype of selectable multiband isolation DPDT switch with transmission line stub resonators	85
4.11	Simulation and measurement results of selectable multiband isolation DPDT switch (case 1), (a) isolation ( $S_{12}$ ) (b) return loss ( $S_{11}$ ) (c) insertion loss ( $S_{14}$ )	87
4.12	Simulation and measurement results of selectable multiband isolation DPDT switch (case 2), (a) isolation ( $S_{12}$ ) (b) return loss ( $S_{11}$ ) (c) insertion loss ( $S_{14}$ )	89
4.13	Simulation and measurement results of selectable multiband isolation DPDT switch (case 3), (a) isolation ( $S_{12}$ ) (b) return loss ( $S_{11}$ ) (c) insertion loss ( $S_{14}$ )	91
4.14	Comparison of simulated isolation of multiband isolation SPDT and DPDT	93
4.15	The prototype of conventional SPDT switch design	95

## 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

APPENDIX	TITLE	PAGE
A	Datasheet of Discrete PIN Diode (BAP64-02)	116
B	Schematic Design of Multiband Isolation SPDT switch	118
C	Schematic Design of Multiband Isolation DPDT switch	119

## 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," *ARPJ 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

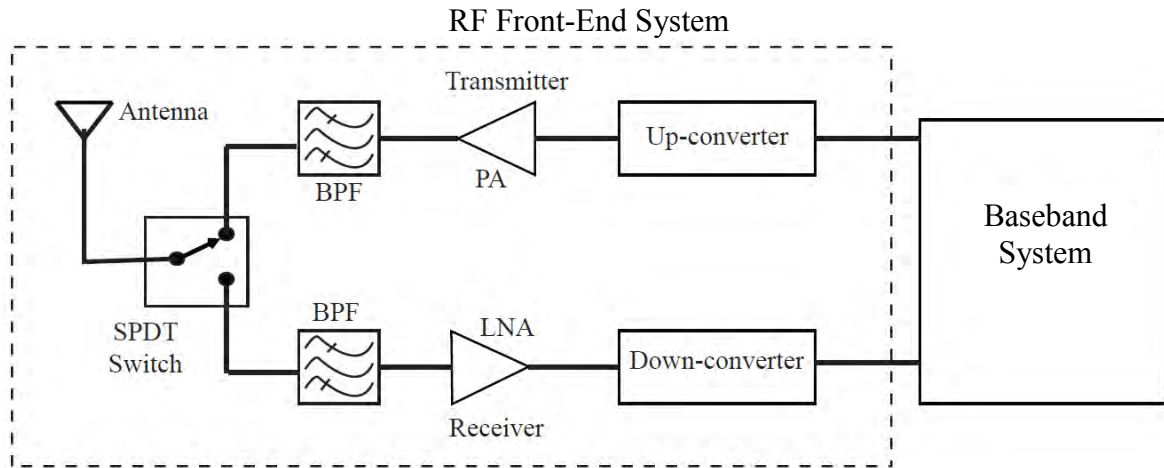
### 1.1 Research Background

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.

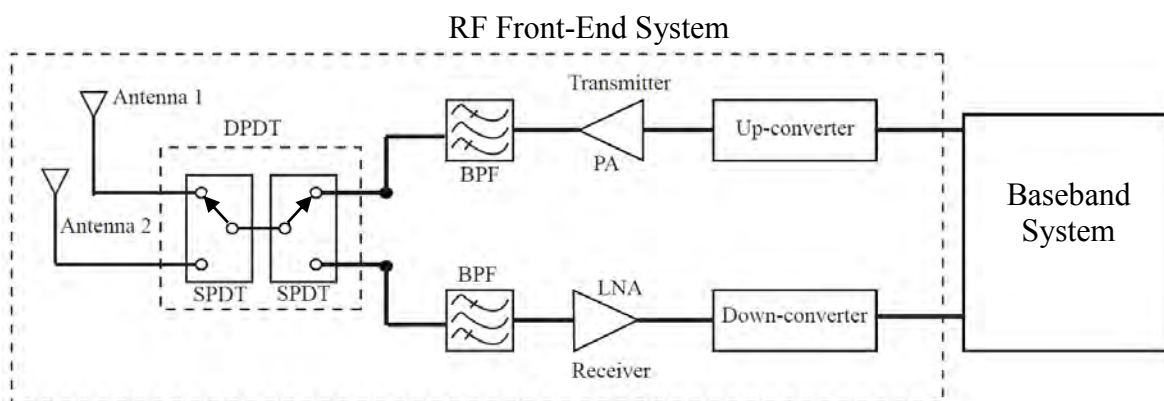
RF switches or commonly known as Double Pole Double Throw (DPDT) switch and Single Pole Double Throw (SPDT) switch are widely used in wireless communication systems to switch signals from antennas to transmitter and receiver paths (Hindle 2010). In another word, their function is supporting Time Division 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 SPST 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,