UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OF ULTRA WIDEBAND ISOLATION OF RF SWITCH FOR MICROWAVE IMAGING IN MEDICAL APPLICATION

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MASTER OF SCIENCE
IN ELECTRONIC ENGINEERING

2021

Faculty of Electronic and Computer Engineering

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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

2021

DECLARATION

I declare that this thesis entitled "Design of Ultra Wideband Isolation of RF Switch for Microwave Imaging in Medical Application" 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 : NURSYAHIRAH BINTI MOHD SANUSI

Date :…………17/11/2021…………………

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 : DR. NOOR AZWAN BIN SHAIRI

Date :…………… 17/11/2021…………….

DEDICATION

Dedicated to ALLAH Almighty, my loving parents and my families for your infinite and unfading love, sacrifice, patience, encouragement and best wishes

ABSTRACT

Microwave imaging is an emerging technology in the medical application similar to that of other technologies, such as X-ray, Magnetic Resonance Imaging (MRI), and Computed Tomography scan (CT scan). In designing a microwave imaging system for medical application, it can use a monostatic radar approach by transmitting a Gaussian pulse (with an ultra wideband (UWB) frequency) through several antennas. RF switches are designed to control the transmit and receive operations of the antennas in the microwave imaging system. However, there will be RF leakages to another unused antennas, thus ultra wideband isolation performance is essential in RF switch design to avoid any signal power leakage between antenna ports during transmit and receive signal operations. The circuit topology was studied to achieved UWB isolation performance for microwave imaging. The fabrication technology PIN diodes was investigate using silicon PIN diodes and silicon glass PIN diodes. The result of S-parameter was analyze in term of return loss, insertion loss and isolation. Therefore, in this research work, two techniques were chosen for further investigation and study for ultra wideband isolation performance of RF switch; they are RF switch topology and fabrication technology of PIN diode. Four different RF switch topologies were investigated in a single pole double throw (SPDT) switch. Concurrently, in the same SPDT switch circuit, two fabrication technologies of PIN diode were selected and investigated as well. They are silicon PIN diodes (from Skyworks Solutions) and silicon glass PIN diodes (from MACOM Technology Solutions). The best RF switch topology in SPDT switch was then selected and used in a single pole eight throw (SP8T) switch, which is a final RF switch design for the front end system of microwave imaging. As result, first, series-shunt-shunt is the best RF switch topology for ultra wideband isolation performance compared to other topologies. It was selected after considering other trade off such as return loss and insertion loss performances. Second, in the fabrication technology of PIN diodes, it was found that the silicon glass PIN diode (MACOM) gave the best isolation compared to silicon PIN diode (Skyworks). In the simulated result, the final design of the RF switch (SP8T) produced 9.3 GHz of isolation bandwidth that can be used for Gaussian pulse bandwidth up to 9.3 GHz (from 1.7 GHz to 11 GHz frequency spectrum). Thus, by combining these two techniques; the series-shunt-shunt topology and silicon glass PIN diode gave the best ultra wideband isolation of RF switch for microwave imaging in medical applications.

REKA BENTUK PEMENCILAN JALUR LEBAR ULTRA BAGI SUIS RF UNTUK PENGIMEJAN GELOMBANG MIKRO DALAM APLIKASI PERUBATAN

ABSTRAK

Pengimejan gelombang mikro adalah teknologi yang muncul dalam aplikasi perubatan yang serupa dengan teknologi lain, seperti sinar-X, Pengimejan Resonan Magnetik dan Imbasan Tomografi Berkomputer. Dalam membina sistem pengimejan gelombang mikro untuk aplikasi perubatan, sistem ini boleh menggunakan kaedah radar monostatik dengan memancar frekuensi denyutan Gaussian (dengan frekuensi jalur lebar ultra (UWB)) melalui beberapa antena. Suis RF direka untuk mengawal penghantaran dan penerimaan operasi antena ini dalam sistem pengimejan gelombang mikro. Walau bagaimanapun, terdapat kebocoran isyarat RF ke antena-antena lain yang tidak digunakan, oleh itu prestasi pemencilan jalur lebar ultra sangat penting dalam reka bentuk suis RF untuk mengelakkan kebocoran kuasa isyarat antara pot antena semasa operasi penghantaran dan penerimaan isyarat tersebut. Kaedah litar telah dikaji untuk mencapai prestasi pemencilan jalur lebar ultra untuk pengimejan gelombang mikro. Teknologi fabrikasi diod PIN telah dikaji menggunakan diod PIN silikon dan diod PIN kaca silikon. Keputusan perimeter S telah dianalisis di dalam konteks kehilangan balikan, kehilangan masukan dan pemencilan. Oleh itu, dalam penyelidikan ini, dua teknik telah dipilih untuk kajian lebih lanjut dan kajian untuk menghasilkan prestasi pemencilan jalur lebar ultra suis RF; iaitu topologi suis RF dan teknologi fabrikasi diod PIN. Empat topologi suis RF yang berbeza dikaji dalam suis satu kutub dua lontar (SPDT). Pada masa yang sama, dalam litar suis SPDT tersebut, dua teknologi fabrikasi diod PIN telah dipilih dan dikaji iaitu diod PIN silikon (dari Skyworks Solutions) dan diod PIN kaca silikon (dari MACOM Technology Solutions). Topologi suis RF yang terbaik dalam suis SPDT kemudian telah dipilih dan digunakan dalam suis satu kutub lapan lontar (SP8T), yang merupakan reka bentuk suis RF akhir untuk sistem hujung depan pengimejan gelombang mikro. Hasilnya, pertama, siri-selari-selari adalah topologi suis RF yang terbaik untuk prestasi pemencilan jalur lebar ultra berbanding dengan topologi-topologi lain. Pilihan ini dibuat setelah mempertimbangkan timbal balik prestasi lain seperti kehilangan balikan dan kehilangan masukan. Kedua, dalam teknologi fabrikasi diod PIN, didapati bahawa diod PIN kaca silikon (MACOM) telah memberikan pemencilan terbaik dibanding dengan diod PIN silikon (Skyworks). Hasil daripada simulasi, telah menunjukkan bahawa reka bentuk akhir suis RF (SP8T) tersebut menghasilkan pemencilan jalur lebar sebanyak 9.3 GHz yang dapat digunakan untuk jalur lebar denyutan Gaussian sehingga 9.3 GHz (dari spektrum frekuensi 1.7 GHz hingga 11 GHz). Oleh itu, menggabungkan kedua-dua teknik ini; topologi siri-selari-selari dan diod PIN kaca silikon telah memberikan pemencilan jalur lebar ultra yang terbaik dalam suis RF untuk pengimejan gelombang mikro dalam aplikasi-aplikasi perubatan.

ACKNOWLEDGEMENTS

In the Name of Allah, Most Gracious, Most Merciful

First and foremost, I would like to thank ALLAH for giving me with strength and courage to complete this thesis. Who gave me an opportunity, courage and patience to carry out this work. I feel privileged to glory His name in the sincerest way through this small accomplishment. I seek His mercy, favour and forgiveness.

I would like to express my deepest gratitude to my Supervisor, Dr. Noor Azwan bin Shairi and co-supervisor. Professor Dr. Zahriladha Zakaria for his constant patience, support and constructive guidance for this project. I would also like to thank the technician at laboratory for his cooperation and support.

Last but not least, I would like to express my appreciation to my beloved parents and my family for the unconditional love and support that let me through the toughest days in my life. To all my friends who shared ideas to make my thesis better, I hope we can have a good grade for our effort. For those whom not stated here, I would like to thank for their help, friendship and countless support to me. May Allah S.W.T. bless all of them for their support and kindness.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

FETs	-	Filed Effect Transistors
LNA	-	Low Noise Amplifier
MEMs	-	Micro-Electro-Mechanicals
MMIC	-	Monolithic Integrated Microwave Circuit
RF	-	Radio Frequency
Rx	-	Receiver
SPDT	-	Single Pole Double Throw
SP8T	-	Single Pole Eight Throw
Tx	-	Transmitter
UWB	-	Ultra Wideband
WLAN	-	Wireless Local Area Network
WiMAX	-	World Interoperability for Microwave Access

LIST OF APPENDICES

LIST OF PUBLICATIONS

The research papers produced and published during the course of this research are as follows:

Journal:

1. Shairi, N. A., Sanusi, N. M., Othman, A., Zakaria, Z., Ibrahim, I. M., 2019. Performance analysis of ultra wideband RF switch using discrete PIN diode in SC-79 package for medical application of microwave imaging. *International Journal of Electrical and Computer Engineering (IJECE)*, 9 (6), 4668 – 4674.

Proceeding:

2. Shairi, N. A., Sanusi, N. M., Zakaria, Z., Ibrahim, I., Othman M. A. and Joret, A., 2019. Ultra wideband SPDT and SP8T Switches using Silicon-Glass PIN Diodes for Microwave Medical Imaging. *2019 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS),* pp. 6-9.

CHAPTER 1

INTRODUCTION

1.1 Research Background

The use of ultra wideband (UWB) technology in medical applications is an emerging research trend in several years back (Jin and Nguyen, 2005). The earliest research report was in 1993, where the utilization of UWB radar in medical application was for body checking and imaging. From that point forward, this innovation is frequently cited as a conceivable other option to remote detecting and imaging medical application. Dissimilar to X-ray imaging, UWB radar tests are performed with non-ionizing electromagnetic waves which are harmless to human. Moreover, UWB technology is rising as a potential solution for high information rate, short range communications and high determination pulsed radar systems. In wireless communication for example, modern UWB communication displays unique features in wideband, high-speed data transmission, low-power consumption and high security comparing to other wireless communication systems (Gao and Huai, 2020). The Federal Communications Commission (FCC) has opened two UWB frequency bands from 3.1 until 10.6 GHz and 22 until 29 GHz that allows researchers and designers to pursue the UWB solutions for commercial applications. Furthermore, FCC and ITU-R refer UWB to fractional bandwidth more than 0.20 or has UWB bandwidth equal or more than 500 MHz, regardless of the fractional bandwidth (Ireland et al., 2011). Mostly, researchers or designers selected frequency spectrum from 3.1 until 10.6 GHz due to the unlicensed band allowed by FCC.