Faculty of Electronics and Computer Engineering

DESIGN OF SWITCHABLE FILTENNA USING SPDT SWITCH FOR WIRELESS COMMUNICATIONS

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

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DECLARATION

I declare that this thesis entitled "Design of Switchable Filtenna Using SPDT Switch for Wireless Communications" 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 : Zayed ……………………………………………...

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Date : 01/08/2022 ……………………………………………..

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.

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Date : 01/08/2022 ……………………………………………………..

DEDICATION

To my beloved mother and father

ABSTRACT

The radio frequency front ends system consists of many functional blocks, such as antenna filters, power amplifiers (PAs), switches, and many more. Conventionally, they are cascaded in wireless systems, which suffer from large size, high loss, or efficiency degradation due to impedance mismatching. One of the measures taken to improve the RF front end is by integrating the filter and antenna in a single structure that possesses both radiation and filtering functions. As a result, the losses, and interference between the antenna and the bandpass filter is tackled. However, the proposed filtennas were of a fixed band of operation and lacked the flexibility to accommodate new services. Reconfigurable filtennas which are able to switch their characteristics according to the requirements are widely adopted in modern RF system applications. Nevertheless, these reconfigurable filtering antennas are not capable of efficiently switching between transmit (Tx) and receive (Rx) channels which restricts their use in Time Division Duplex (TDD) RF front-end systems. Therefore, in this research project, a two-port antenna with the integrated filtering and transmit (Tx) – receive (Rx) switching functions for Time Division Duplex (TDD) transmission is proposed. RF signals are fed to a square radiating patch through two orthogonal ports to excite Tx and Rx modes. The filtering function is implemented by incorporating two symmetric square ring resonators working as–bandpass filter into both feeding line paths to increase the selectivity of each channel and improve the isolation between the two ports. Frequency reconfiguration between the two ports is realised by etching a rectangular slot in the feeding point for each path and placing a PIN diode in suitable places. The measurement results agree well with the simulated values, with a return loss better than -15 dB showing the maximum broadside realised gain of 2.4 dB at a centre frequency of 2.4 GHz, with an omnidirectional radiation pattern and port-to-port isolation of over 40 dB, which is sufficient to reduce channel interference. The benefits of the proposed switchable filter integrated antenna include satisfactory performance in terms of filtering, radiation, flat in-band gain response, out-of-band frequency suppression, and high port to port isolation when it is connected with either Tx or Rx port. Hence, the proposed filtering antennas with Tx/Rx mode reconfiguration are a good candidate for use in modern TDD RF front-end circuits that requires multifunctional operation devices.

REKA BENTUK FILTENNA BOLEHALIH MENGGUNAKAN SUIS SPDT UNTUK KOMUNIKASI WAYARLES

ABSTRAK

Sistem hujung depan frekuensi radio (RF) terdiri daripada banyak blok berfungsi, seperti penapis antena, penguat kuasa (PA), suis, dan sebagainya. Secara konvensional, ianya disusun secara berjujukan dalam sistem wayarles, yang mengalami masalah dari segi saiz yang besar, kehilangan tinggi, atau penurunan kecekapan kerana galangan yang tidak sepadan. Salah satu langkah yang diambil untuk penambahbaikan hujung depan RF adalah dengan menggabungkan penapis dan antena dalam struktur tunggal yang memiliki fungsi penyinaran dan penyaringan. Akibatnya, kerugian, dan gangguan antara antena dan penapis jalur lebar dapat ditangani. Walau bagaimanapun, filtena yang dicadangkan beroperasi secara tetap dan tidak mempunyai fleksibiliti untuk menampung perkhidmatan baru. Filtena yang boleh dikonfigurasi semula yang dapat menukar ciri-cirinya mengikut keperluan sedang diguna pakai secara meluas dalam aplikasi sistem RF moden. Walaupun begitu, antena penapisan yang dapat dikonfigurasikan ini tidak dapat beralih antara pemancar (Tx) dan penerima (Rx) dengan cekap yang tidak dapat digunakan dalam sistem hujung depan RF Pembahagian Masa Dupleks (TDD). Oleh itu, projek penyelidikan ini mencadangkan antena dua port dengan fungsi penapisan dan pemancar (Tx) - penerima (Rx) bersepadu untuk penghantaran TDD. Isyarat RF disalurkan ke tampalan penyinaran bersegi empat melalui dua port yang berserenjang untuk menghasilkan mod Tx dan Rx. Fungsi penapisan dilaksanakan dengan memasukkan dua resonator cincin bersegi empat bersimetri yang berfungsi sebagai dua penapis jalur lepas dalam kedua-dua saluran masukan untuk meningkatkan pemilihan setiap saluran dan meningkatkan pengasingan antara kedua-dua port. Konfigurasi frekuensi antara kedua-dua port dicapai dengan menghasilkan satu slot segi empat tepat di satu titik saluran masukan dan meletakkan diod PIN di tempat yang sesuai. Hasil pengukuran menunjukkan persamaan dengan hasil yang telah disimulasi, dengan kehilangan balikan yang lebih baik daripada -15 dB yang menunjukkan maksimum lebar gandaan terhasil sebanyak 2.4 dBi pada frekuensi tengah 2.4 GHz, dengan corak radiasi serata tumpuan dan pengasingan antara port yang lebih daripada 40 dB bagi mengurangkan gangguan saluran. Manfaat yang terhasil daripada reka bentuk yang dicadadangkan ini termasuk prestasi yang memuaskan dari segi penapisan, penyinaran, tindak balas gandaan yang sekata, penindasan frekuensi di luar jalur, dan pengasingan antara port yang tinggi ketika disambungkan dengan port Tx atau Rx . Oleh itu, antena penapisan yang dicadangkan dengan konfigurasi mod Tx/Rx adalah struktur yang baik untuk digunakan pada hujung depan TDD RF moden yang memerlukan peranti beroperasi dalam pelbagai fungsi.

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LIST OF ABBREVIATION

ADS	-	Advanced Design System
AUT	-	Antenna Under Test
BPF	-	Bandpass Filter
BSF	-	Bandstop Filter
BW	-	Bandwidth
CLR	-	Coupled Line Resonator
CMOS	-	Complementary Metal Oxide Semiconductor
Co-pol	-	Co-polarization
CST	-	Computer Simulation Technology
dB	-	Decibel
DC	-	Direct Current
DGS	-	Defected Ground Structure
DPS	-	Defected Patch Structure
DSRR	-	Double Split Ring Resonator
E	-	Elevation Plane
EM	-	Electromagnetic
FET	-	Field-Effect Transistors
FR4	-	Flame Retardant 4
GaAs	-	Gallium Arsenide

GHz	-	Giga Hertz
H	-	Azimuth Plane
HPF	-	Highpass Filter
LNA	-	low noise amplifier
LPF	-	Lowpass Filter
LTE	-	Long Term Evolution
MEMs	-	Micro Electro Mechanicals
MIMO	-	Multi-input Multi-output
mm	-	Millimeter
MMIC	-	Monolithic Microwave Integrated Circuit
NSR	-	No uniform Sub Resonator
OC	-	Open Circuit
PCB	-	Printed Circuit Board
pHEMT	-	Pseudomorphic High Electron Mobility Transistor
RF	-	Radio Frequency
RSS	-	Resonant Stub Structure
SC	-	Short Circuit
SiGe	-	Silicon Germanium
SPDT	-	Single Pole Double Throw
SPST	-	Single Pole Single Throw
SRR	-	Split Ring Resonator
SW	-	Ideal Switch
Tx/Rx	-	Transmit and Receive
TDD	-	Time Division Duplex

UWB	-	Ultra-Wide Band
VNA	-	Vector Network Analyser
VSWR	-	Voltage Standing Wave Ratio
WiFi	-	Wireless Fidelity
WLAN	-	Wireless Local Area Network
x-pol	-	Cross Polarization

LIST OF SYMBOLS

an	-	Incident Wave
bn	-	Reflected Wave
c	-	Speed of Light
C	-	Capacitance
d	-	Height of the substrate
$\mathscr{E}r$	-	Relative Permittivity of the Substrate
ϵ	-	Insertion Loss Ripple
fo	-	Center Frequency
fc	-	Cutoff Frequency
g	-	Width of the U-shaped slot
I	-	Current
j	-	Imaginary
L	-	Inductance
R	-	Resistance
RL	-	Return Loss
sin	-	Trigonometry Function
S11	-	Reflection Coefficient at port 1
S22	-	Reflection Coefficient at port 2
S12	-	Transmission Coefficient at port 1
S21	-	Transmission Coefficient at port 2