UNIVERSITI PUTRA MALAYSIA

AMPLITUDE SHIFT- KEYING DEMODULATOR CIRCUIT FORBIO-IMPLANTABLE MICRO-SYSTEM STIMULATOR

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AMPLITUDE SHIFT- KEYING DEMODULATOR CIRCUIT FOR BIO-IMPLANTABLE MICRO-SYSTEM STIMULATOR

By

MOKHALAD KHALEEL HASSOON

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

September 2016

DEDICATION

THIS THESIS DEDICATED

TO

MY BELOVED FAMILY.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

AMPLITUDE SHIFT- KEYING DEMODULATOR CIRCUIT FOR BIO-IMPLANTABLE MICRO-SYSTEM STIMULATOR

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September 2016

Chairman : Nasri Bin Sulaiman, PhD
Faculty : Engineering

Recently there has been a lot of attention to the development of battery less implantable electronic devices for medical treatment and rehabilitation, these developments need to flexible high speed communication between the external equipment and implanted part. Nowadays, wireless power transfer (WPT) is used for transferring power and data to bio-implantable device. The main challenges in the design of biomedical implants circuits are data rate, size, power consumption and feasibility.

In this thesis, proposes a new technique with the objective to overcome the above problems. Firstly, develop transcutaneous implantable telemetry system by design new structure of amplitude shift keying demodulator with low power consumption. Secondly, optimize and modify the geometries for inductive links based on the spiral circular coil, and testing and simulating the coil's performance on air. Thirdly, modifying efficient sub-electronic circuits for both the external and internal components.

The modified rectifier and voltage regulator without a thermal protection circuit are designed in which passive elements are removed to generate adequate and stable 1.8 V DC. The new structure ASK demodulator is then designed based on voltage divider, small capacitor, one digital invertor to envelope signal and one cascade inverters to collect a synchronized demodulated signal data with minimum error, thereby no need to use comparator to extract the data and removing delay-locked loops (DLL) circuits for data synchronization. For this, professional Pspice 16.6 software is used to design the full system. The performance of the developed spiral circular coils is designed and simulated on air in lower frequency 6.78 MHz Industrial Scientific Medical (ISM) using the commercial HFSS 15.0 software.

The system is operated at industrial scientific and medical (ISM) 6.78 MHz band with 12.5% modulation index to transfer data 500 Kb/s. The coupling efficiency between the two coils in the worst case is 68.77%, and for the optimum case is up to

74.47%. The transmitter and receiver coils used in the system offer 15 mm of distance transmission between coils. The gain surrounding coils is then simulated and plotted in the elevation and azimuthal planes. This demonstrates that the gain is constant and conforms to the omnidirectional pattern associated with such loop antennas. Furthermore, the driving application of the developed implanted micro-system can be used to stimulate nerves, muscle, implanted cochlear and may be also used for brain pacemaker implantation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

LITAR PENYAHMODULAT AMPLITUD PERALIHAN MENAIP UNTUK PERANGSANG SISTEM MIKRO BIO-IMPLAN

Oleh

MOKHALAD KHALEEL HASSOON

September 2016

Pengerusi : Nasri Bin Sulaiman, PhD
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Baru-baru ini banyak perhatian diberikan kepada pembangunan peranti implan elektronik tanpa bateri untuk rawatan perubatan dan pemulihan. Perkembangan ini memerlukan komunikasi kelajuan tinggi yang fleksibel antara peralatan luaran dan bahagian yang diimplan. Pada masa kini, pemindahan kuasa tanpa wayar (WPT) digunakan untuk memindahkan kuasa dan data kepada peranti bio-implan. Cabaran utama dalam reka bentuk litar implan bioperubatan adalah kadar data, saiz, penggunaan kuasa dan kebolehlaksanaan.

Tesis ini mencadangkan satu teknik baru yang bertujuan mengatasi masalah di atas. Pertama, dibangunkan sistem telemetri implan merentasi kulit dengan mereka struktur baru penyahmodulat amplitud peralihan menaip dengan penggunaan kuasa rendah merentasi kulit. Kedua, mengoptimumkan dan mengubahsuai geometri untuk pautan induktif berdasarkan lingkaran gegelung bulat, dan menguji dan mensimulasikan prestasi gegelung terhadap udara. Ketiga, mengubahsuai litar sub-elektronik untuk kedua-dua komponen luaran dan dalaman.

Penerus dan pengatur voltan yang diubahsuai tanpa litar perlindungan haba direka bentuk supaya unsur-unsur pasif dikeluarkan untuk menjana DC 1.8 V yang mencukupi dan stabil. Struktur baru penyahmodulat ASK kemudiannya di reka berdasarkan pembahagi voltan, kapasitor kecil, satu penyongsang digital untuk sampul isyarat dan satu penyongsang lata untuk mengumpul data isyarat yang dinyahmodulatkan dan disegerakkan dengan kesilapan minimum. Dengan itu, bandingan tidak perlu digunakan untuk mengekstrak data dan mengeluarkan litar gelung lewat terkunci (DLL) untuk penyegerakan data. Perisian Pspice 16.6 digunakan untuk mereka bentuk sistem penuh. Prestasi gegelung bulat lingkaran yang dibangunkan direka dan disimulasikan ke atas udara pada frekuensi yang lebih rendah pada jalur Perindustrian, Saintifik dan Perubatan (ISM) 6.78 MHz, dengan menggunakan perisian komersial HFSS 15.0.

Sistem ini beroperasi pada jalur Perindustrian, Saintifik dan Perubatan (ISM) 6.78 MHz dengan indeks pemodulatan 12.5% untuk memindahkan data sepantas 500 Kb/s. Kecekapan gandingan antara dua gegelung dalam kes yang paling teruk adalah 68.77%, dan untuk kes optimum adalah sehingga 74.47%. Gegelung pemancar dan penerima yang digunakan dalam sistem tersebut menawarkan jarak penghantaran sepanjang 15 mm antara gegelung. Keuntungan pada gegelung sekitar kemudian disimulasikan dan diplot dalam satah dongakan dan azimut. Ini menunjukkan bahawa keuntungan itu adalah tetap dan mematuhi pola dalam semua arah yang berkaitan dengan antena gelung tersebut. Tambahan pula, aplikasi pemanduan sistem mikro implan yang dibangunkan boleh digunakan untuk merangsang urat saraf, otot, implan koklea, dan boleh juga digunakan untuk implantasi perentak otak.

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I certify that a Thesis Examination Committee has met on 6 September 2016 to conduct the final examination of Mokhalad Khaleel Hassoon on his thesis entitled "Amplitude Shift-Keying Demodulator Circuit for Bio-Implantable Micro-System Stimulator" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

AC	Alternating Current
ASK	Amplitude Shift Keying
AM	Amplitude Modulation
BW	Band width
BPSK	Binary Phase Shift keying
BFPK	Binary Frequency Shift Keying
BPF	Band Pass Filter
BJT	Bipolar Junction Transistor
BIOSTEC	Biomedical Signals Telecommunication
CMOS	Complementary Metal oxide Semiconductor
CE-PA	Class E Power Amplifier
CF-PA	Class F Power Amplifier
DAC	Digital to Analogue Converter
DC	Direct Current
DEPSK	Differential Encode Phase Shift Keying
DLL	Delay locked loop
EMG	Electromyography
EGG	Electroencephalograph
EOG	Electrooculography
ECG	Electrocardiograph
EMI	Electromagnetic Interface
EEG	Electroencephalography
EMF	Electromagnetic Field

FDTD	Finite-difference time domain
FCC	Federal communication commission
FSK	Frequency shift keying
FS	Frequency Synthesizer
FM	Frequency Modulation
FEM	Finite-element-method
FPGA	Field Programmable Gate Array
FOM	Figure of Merit
GND	Ground
HFSS	High Frequency Electromagnetic Field Simulation
HF	High Frequency
IBM	Implantable Biomedical Micro-system
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of electrical and electronics engineers
ISM	Industrial standard medical
K	Coupling coefficient
LC	Inductance and Capacitance
L	Inductance
MICS	Medical Implant Communications Service
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
OOK	On-Off Keying
PA	Power Amplifier
PCB	Printed Circuit Board
PSK	Phase Shift Keying

PWM	Pulse Width Modulation
PLL	Phase Looked Loop
PSCC	Printed Spiral Circular Coil
PP	Parallel-to-Parallel
PN	Pseudo Sequence
Q	Quality Factor
QAM	Quadrate Amplitude Modulation
RFID	Radio Frequency Indication
RF	Radio Frequency
R	Resistance
Rx	Receiver Signal
S	Space Separated Coil Turns
SS	Serial to serial
SP	Serial to Parallel
SOC	System-on-Chip
TX	Transmitter Signal
TET	Transcutaneous Energy Transfer System
UHF	Ultra High Frequency
VHDL	Very High Design Language
VHF	Very High Frequency
VCO	Voltage Control Oscillator
W	Width of Coil Turn
WCP	Wireless Coupling Power
WPT	Wireless power transfer

LIST OF SYMBOLS

α	Attenuation
θ	Azimuthally plane
σ	Conductivity
η	Efficiency
φ	Fill factor
M	Mutual Coupling
µ	Permeability
Φ	Magnetic Flux
B	Magnetic flux density
Ω	Ohm
ω	Angular frequency
ε	Permeability
π	Pie
δ	Tissue Depth
W	Watts
Z	Impedance

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