SELF-HARMONICS SUPPRESSION RECTENNA FOR WIRELESS POWER HARVESTING

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LIST OF ABBREVIATIONS

WPT	-	Wireless Power Transmission
MPT	-	Microwave Power Transmission
RF	-	Radio Frequency
DC	-	Direct Current
AC	-	Alternating Current
FET	-	Field Effect Transistor
TWT	-	Travelling Wave Tube
EMI	-	Electromagnetic Interference
RFID	-	Radio Frequency Identification
Hz	-	Hertz
GHz	-	Gigahertz
kW	-	Kilowatt
MW	-	Megawatt
dB	-	Decibel
PCB	-	Printed Circuit Board
TM	-	Transverse Magnetic
TE	-	Transverse Electric
CP	-	Circular Polarization
LP	-	Linear Polarization
RHCP	-	Right Hand Circular Polarization
LHCP	-	Left Hand Circular Polarization
PBG	-	Photonic Band Gap

DGS	-	Defected Ground Structure
CMRC	-	Compact Microstrip Resonant Cell
CPW	-	Coplanar Waveguide
SIR	-	Step Impedance Resonators
SPDT	-	Single Polar Double Throw
VSWR	-	Voltage Standing Wave Ratio
MPPT	-	Maximum Power Point Tracking
FCC	-	Federal Communications Commission

LIST OF SYMBOLS

h	-	Height of the substrate
W	-	Width of the rectangular patch
L	-	Length of the rectangular patch
a	-	Radius of the circular patch
ε_r	-	ε_r is dielectric constant
ε_{eff}	-	Effective dielectric constant
L_{eff}	-	Effective length
λ	-	Wavelength
f	-	Frequency
f_r	-	Resonance frequency
L	-	Inductor
C	-	Capacitor
Y	-	Admittance
Z	-	Impedance
G	-	Conductance
V_D	-	Voltage of the diode
V_p	-	Peak Voltage
V_j	-	Diode junction voltage
R_j	-	Diode junction resistance
C_j	-	Diode junction capacitance

Likutena Berpenindasan Harmonik Sendiri Untuk Penuaian Kuasa Tanpa Wayar

ABSTRAK

Pembangunan dan analisa beberapa reka bentuk sistem likutena berpenindasan harmonik-sendiri untuk penuaian kuasa tanpa wayar dibentangkan. Tujuan likutena yang berpenindasan harmonik-sendiri adalah untuk mengelakkan penggunaan litar penapis harmonik didalam penapisan isyarat harmonik dan gangguan elektromagnet (EMI) dalam sistem likutena. Motivasi untuk kerja-kerja ini telah diilhamkan oleh keperluan rekaan terkini yang menuntut saiz yang padat, kos yang rendah, kecekapan sistem likutena yang tinggi dan juga yang sangat penting ialah struktur senibina yang mudah untuk mengurangkan ralat semasa proses fabrikasi. Sebagai tindak balas kepada tuntutan yang mencabar ini, empat reka bentuk antena tampal mikrostrip berpenindasan harmonik-sendiri telah disimulasikan, dibikinkan, diukur dan dianalisa. Dua binaan boleh dikelaskan dalam polarisasi linear manakala dua lagi binaan mempamerkan sifat-sifat polarisasi bulatan. Teknik untuk menindas harmonik-sendiri yang telah diperkenalkan adalah belahan, slot dan takuk di struktur antena tampal dan puntung terbuka di mikrostrip suapan. Selain itu, teknik pencacatan keatas struktur satah bumi diperkenalkan untuk mengurangkan saiz antena tampal. Teknik pengusikan telah diperkenalkan keatas bentuk asas segi empat tepat dan bulat antena tampal untuk menghasilkan gelombang berpolarisasi bulatan. Hasilnya, bentuk segi empat tepat menjadi bentuk yang segiempat yang hampir sama, manakala bentuk yang bulat menjadi bentuk elips. Disamping itu, satu antena bersifat dwi-polarisasi bulatan juga dicadangkan. Untuk mendapatkan voltan keluaran yang tinggi, antena tampal penindasan mikrostrip tatasusun yang berpenindasan harmonik-sendiri juga telah dibangunkan. Didalam pemprosesan penukaran isyarat gelombang radio kepada isyarat arus terus, beberapa reka bentuk litar penerus telah dicadangkan. Rangkaian padanan bagi litar penerus yang dicadangkan mampu untuk mempunyai padanan impedans yang baik untuk membenarkan kuasa yang maksima dipindahkan. Didalam kerja-kerja simulasi, aplikasi *CST Microwave Simulator* dan *Advanced Design System (ADS)* telah digunakan. Sebagai pengesahan keputusan teori dan simulasi, prototaip bagi semua reka bentuk telah dibikinkan dan diukur. Untuk perbandingan, prototaip antena tampal mikrostrip biasa berbentuk segiempat dan bulatan juga direka dan dibikinkan. Hasil daripada pengukuran prototaip menunjukkan keputusan yang cemerlang dan selaras dengan keputusan simulasi. Kehilangan pulangan bagi antena yang telah diukur menunjukkan ia hanya bergema pada frekuensi yang asas sahaja, manakala pada frekuensi harmonik, magnitud kehilangan pulangan telah ditindas dengan jayanya. Dalam ujikaji sistem penuaian kuasa tanpa wayar, didapati peningkatan yang ketara didalam kuasa keluaran berjaya dicapai berbanding dengan antena rujukan tanpa penindasan harmonik. Semua reka bentuk telah direalisasikan dengan menggunakan proses piawai PCB. Dengan itu, teknik fabrikasinya adalah sangat mudah dengan kos yang murah, oleh itu ia boleh dengan mudah besar-besaran.

Self-Harmonics Suppression Rectenna for Wireless Power Harvesting

ABSTRACT

The development and analysis of several designs of self-harmonic suppression rectenna for the wireless power harvesting system are presented. The purpose of self-harmonic suppression rectenna is to eliminate the using of a harmonic filter circuit in filtering the harmonic radiation and electromagnetic interference (EMI) in rectenna system. The motivation for this work has been inspired by the need for compact size, low cost, high efficient rectenna system and also very important is the design structure is simple in order to reduce the error during the fabrication process. In the response to these challenging demands, four designs of self-harmonic suppression microstrip patch antenna have been simulated, fabricated, measured and analysed. Two designs can be classified in linear polarization while the other two designs exhibit the circular polarization properties. The technique to suppress the harmonics which have been introduced are the slits, slot and notch at the patch structure and an open stub at the microstrip feeding line. Also, a defected ground structure technique is applied to reduce the size of the patch antenna. The perturbation technique has been introduced to the basic rectangular and circular shapes microstrip patch antenna to produce circular polarization property. As a result, the rectangular shape becomes a nearly-square shape, while the circular shape becomes an elliptical-shape. Subsequently, a dual polarization of circularly polarized property is also proposed. To obtain high output voltage, a self-harmonic suppression microstrip patch array antenna is developed. For conversion of RF-to-DC signal, a few designs of rectifier circuits are proposed. The proposed rectifier matching networks are capable to provide a good impedance matching with a wide range of incident power. All the simulation has been done by using CST Microwave Simulator and Advanced Design System (ADS). To validate the theory and simulation, the prototypes of all designs have been fabricated and measured. For the comparison, the prototype of the conventional linear polarization (LP) rectangular and circular microstrip patch antenna are also have been designed and fabricated. The measurements show an excellent result and is in line with the simulated result. The measured of the return loss of the antennas show it resonate at the fundamental frequency, while at the harmonic frequencies, the magnitude of the return loss were suppressed successfully. In the wireless power harvesting system experimental work, it is seen that a significant improvement of the output power is achieved compared to the reference antenna without harmonic suppression. All design has been realized by using a standard PCB process. Therefore, the fabrication technique is very simple with a very cheap cost, thus it can be conveniently mass-produced.

CHAPTER 1

INTRODUCTION

1.1 Overview

In the past few decades, many types of technology have been introduced, developed and implemented in an attempt to solve the crisis of the world's electricity sources due to the diminishing coal, oil and gas reserves. Nowadays, one of the main concerns of every scientist and researcher in introducing or developing any new technology is the impact that its implementation will have on the environment. This awareness stems from the effect of the carbon emissions, which can cause various problems to the environment and human life that result from the generation of electricity using existing technology, which mostly depends on fossil fuels as a burning source to drive the electrical generator.

Although nuclear energy can be categorized as a clean and efficient energy, a suitable and safe method of disposal of nuclear waste has not yet been discovered, and while the generation of hydroelectricity can be categorized as a renewable source, the construction of hydroelectric dams required a large area of land that would involve the destruction of the environment. Such issues have been given attention in every exploration of the development of new alternative sources of electric energy. As a result, a variety of technologies and methods to obtain new sources of electricity have been introduced and developed. One of the most promising technology that has introduced recently is the energy harvesting technology. Energy harvesting is the process of conversion of any energy to electrical energy, such as sound energy, vibration energy, solar energy, wind energy, ocean wave energy, thermal energy and