AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
CAIRO-EGYPT
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Reconfigurable Antennas Using MEMS Technology

A Thesis
Submitted in partial fulfillment of the requirements of the degree of
Master of Science in Electrical Engineering

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STATEMENT

This Thesis is submitted to Ain Shams University in partial fulfillment for the degree of Master of Science in Electrical Engineering (Electronics and Communication Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

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ABSTRACT

John Elias Yanni Kiriazi, "Reconfigurable Antennas Using MEMS Technology", Master of Science dissertation, Ain Shams University, ٢٠٠٥.

Key words: MEMS technology, bulk micromachining, series MEMS switch, dipole antenna, slot antenna.

Recently, reconfigurable antennas have found many applications due to their reduced size, weight and cost. A reconfigurable antenna is a single aperture that can be intentionally modified by means of some external controls to change its radiation characteristics. Current trends in wireless communications; military, satellite, biomedical and mobile communications enhance the development of such multi-standard devices. In addition, the recent development in MEMS (Micro Electro Mechanical Systems) technology made these devices possible to implement and satisfy the current requirements.

The main objective of this thesis is to study the feasibility of using MEMS technology for the implementation of reconfigurable multi-band antennas and to demonstrate the effect of the MEMS switches on the whole antenna performance compared to the ideal switch case.

The first designed antenna is a reconfigurable dual-band dipole antenna using series MEMS switches and operating at the ٤.٨٦ and ٨.٩٨ GHz frequency bands. The dipole is printed on a ٥٢٥µm High Resistivity Silicon (HRS) substrate coated by a ١.٤µm ($SiO_{٢}/Si_{٣}N_{٤}$) layer. The dipole is designed to be directly fed by a differential feed. The effects of the series MEMS switches on the antenna performance are then studied. The design is performed using the ٣D electromagnetic simulator HFSS®.

Using the designed series MEMS switches, the obtained antenna return loss is ١٠.٢ dB and ٢١.٦ dB, at the lower and upper frequencies, respectively. However, comparable to the case of ideal switches, the resonance frequency decreased by ٠.٤% and of ٢.٨% at the lower and upper frequencies, respectively. The antenna, including the MEMS switches, has bandwidth of ١.٩% and ١٣.٦% at the lower and upper frequencies, respectively. The antenna directivity is ٢ dB at the lower frequency, and is ٣ dB at the upper frequency. However, the drawbacks of this design are mainly the high cost due to the use of a relatively large area of HRS chip and the problems associated with a differentially-fed antenna at such high frequency band.

Consequently, in order to overcome the drawbacks of the previous design, another topology has been investigated. It is a CPW fed slot-line dipole over a standard silicon substrate (١١-١٥ Ω.cm) coated by a ٢٠µm Benzocyclobutene (BCB) layer. The later helps as a shield for the electric field lines from the lossy silicon substrate. In addition, trenches are etched by bulk micromachining just below the slot and the feed line to reduce the losses caused by the silicon substrate. The antenna is designed for operation at ٢٤ and ٣٤ GHz. This topology provides a compact area of ٠.٦٣٦ $\text{cm}^{٢}$. The effect of the MEMS switches compared to the ideal switches case is also studied.

Finally, for measurements purposes, the slot antenna topology is scaled down on a dielectric substrate (ε_r=٣.٥) for operation at ٢.٤ and ٣.٤ GHz. However, since MEMS switches in a compact packaged form were not available, the reconfigured slot was implemented using ideal switches. This is of no inconvenience since the effect of the MEMS switch, based on the conducted study, is minor at frequencies below ٥ GHz. The measured data were comparable to the simulation results.

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LIST OF SYMBOLS

A	Magnetic vector potential
Au	Gold
BW	Impedance bandwidth
c	Velocity of light
C_{in}	Cosine integral
d	Elements spacing
D	Directivity
E	Electric field
F	Electric vector potential
F_n	Normalized field pattern
f_L	Lower resonant frequency
f_H	Higher resonant frequency
GaAs	Gallium Arsenide
h	Substrate thickness
H	Magnetic field
I	Electrical current
J_s	Electric surface current density
k_o	Free space wave number
L	Length of the planar antenna
M_s	Magnetic surface current density
P_r	Radiated power
P_{ohm}	Power dissipated as ohmic losses
P_{surf}	Power dissipated as surface waves
R	Resistance
S	Power density
Si	Silicon
$Si_{٣}N_{٤}$	Silicon Nitride
$SiO_{٢}$	Silicon Dioxide
υ	Phase velocity
β	Wave phase constant
η	Medium wave impedance

η_r	Radiation efficiency
Ω	Ohms
Z_A	Antenna input impedance
Z_c	Characteristic impedance
ε_{eff}	Effective dielectric constant
ε_o	Permittivity of free space
ε_r	Relative dielectric constant
λ	Wavelength
μ_o	Permeability of free space
ρ	Volume charge density

LIST OF ABBREVIATIONS

AF	Array Factor
AMTI	Airborne Moving-Target-Indicator
BCB	Benzo-Cyclo-Butene
CPW	Coplanar Waveguide
ELINT	Electronic Intelligence
FOPEN	Foliage Penetration
HRS	High Resistivity Silicon
ICP	Inductively Coupled Plasma
LIGA	acronym from German words that means Lithography, Electroplating, and molding
MEMS	Microelectromechanical Systems
MMIC	Monolithic Microwave Integrated Circuits
PMMA	Polymethyl Methacrylate
RF	Radio Frequency
RIE	Reactive-Ion Etching
RPM	Reconfigurable Patch Module
SAR	Synthetic Aperture Radar
SCREAM	Single-Crystal Reactive Etching And Metallization
TTD	True-Time Delay
UAV	Unmanned Arial Vehicle
VSWR	Voltage Standing Wave Ratio

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