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It is certified that the work contained in the thesis titled **"*MIMO Antennas: Design, Development, and Implementation using Printed Monopole Antennas*"** by **"*Arun Kumar Saurabh (Roll No.: 17091015)*"** has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

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DECLARATION BY THE CANDIDATE

I, ***Arun Kumar Saurabh (Roll No.: 17091015)***, certify that the work embodied in this thesis is my own bonafide work and carried out by me under the supervision of ***Prof. Manoj Kumar Meshram***, from **25/07/2017** to **20/06/2022**, at the **Department of Electronics Engineering**, Indian Institute of Technology (Banaras Hindu University), Varanasi. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged, given credits to and referred to the research workers wherever their works have been cited in the text and the body of the thesis. I further declare that I have not willfully copied any other's work, paragraphs, text, data, results, *etc.*, reported in journals, books, magazines, reports dissertations, theses, *etc.*, or available at websites and have not included them in this thesis and have not cited as my own work.

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Date: ***Arun Kumar Saurabh***

This thesis is dedicated to

[My Beloved Parents]

&

[Family Members]

Contents

List of Figures

List of Tables

List of Abbreviations

1G	First-Generation
5G	Fifth-Generation
MIMO	Multiple Input Multiple Output
SISO	Single Input Single Output
SIMO	Single Input Multiple Output
MISO	Multiple Input Single Output
CC	Channel Capacity
SE	Spectral Efficiency
AWGN	Additive White Gaussian Noise
CSI	Channel State Information
SINR	Signal to Interference Noise Ratio
MC	Mutual Coupling
IoT	Internet of Things
ESA's	Electrically Small Antennas
PCB	Printed Circuit Board
PPMA	Printed Planar Monopole Antenna
TE	Total Efficiency
ME	Multiplexing Efficiency
IID	Independent and Identically Distributed
ECC	Envelope Correlation Coefficient
DG	Diversity Gain
MEG	Mean Effective Gain
TARC	Total Active Reflection Coefficient
CCL	Channel Capacity Loss
EMC	Electromagnetic Coupling
EM	Electromagnetic
UWB	Ultrawideband
DGS	Defected Ground Structure
NL	Neutralization Line
SWB	Super Wideband
SRR	Split Ring Resonator

CSRR	Complementary Split Ring Resonator
EBG	Electromagnetic Band Gap
MSS	Metasurface Superstrate
MTMA	Metamaterial Absorber
WLAN	Wireless Local Area Network
UMTS	Universal Mobile Telecommunications System
LTE	Long Term Evolution
QSCA	Quasi Self Complementary Antenna
FSS	Frequency Selective Surface
RCS	Radar Cross Section
Wi-MAX	Worldwide Interoperability for Microwave Access
Wi-Fi	Wireless Fidelity
Sub-6 GHz	Spectrum Below 6 GHz
ISM	Industrial, Scientific and Medical
CL-FSS	Closed-Loop Frequency Selective Surface
HFSS	High Frequency Structure Simulator
VNA	Vector Network Analyzer
IoV	Internet of Vehicle
NR	New Radio
RSLR	Radial Stub Loaded Resonator
CRDN	Coupled Resonator Decoupling Network
WPAN	Wireless Personal Area Networks
GPS	Global Positioning System
SICBS	Substrate Integrated Cavity-Backed Slot
V2P	Vehicle-to-Person
V2X	Vehicle-to-Everything
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
PCRs	Parallel Coupled Resonators
AMC	Artificial Magnetic Conductor
DRA	Dielectric Resonator Antenna
GCPW	Grounded Coplanar Waveguide
SIC	Substrate Integrated Cavity

List of Symbols

λ	Wavelength
Z_{in}	Input Impedance
f_r	Resonant Frequency
c	Speed of Light
ε_{reff}	Effective Relative Dielectric Constant
$\eta_{rad(i)}$	Radiation Efficiency of i^{th} Antenna Element
$\eta_{tot(i)}$	Total Efficiency of i^{th} Antenna Element
$\eta_{mis(i)}$	Mismatch Efficiency of i^{th} Antenna Element
$\tilde{\eta}_{mux}$	Multiplexing Efficiency
$\rho_e(i,j,N)$	Envelope Correlation Coefficient
Ω	Solid Angle
XPR	Cross-Polarization Power Ratio
$G_{\theta i}(\Omega)$	θ-Polarized 3-D Power Gain Patterns
$G_{\varphi i}(\Omega)$	φ-Polarized 3-D power Gain Patterns
$P_\theta(\Omega)$	θ-Polarized Components of Angular Power Density
$P_\varphi(\Omega)$	φ-Polarized Components of Angular Power Density
Γ_a^t	Total Active Reflection Coefficient
k	Wavenumber
ω	Angular Frequency
μ	Effective Permeability
ε	Effective Permittivity
ε_r	Relative Permittivity
μ_r	Relative Permeability
λ_0	Free-Space Wavelength
λ_g	Guided Wavelength
$tan\ \delta$	Loss Tangent
Z_{11}	Input Impedance for Port 1
Ω	Ohm