Some Investigations on Patch Antennas for Hyperthermia Applications

Thesis submitted in partial fulfillment

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Doctor of Philosophy

By

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This thesis is dedicated

to my family

For their endless love, support and encouragement

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Date: **(Azharuddin Khan)**

Preface

Cancer is a formidable adversary that continues to challenge the boundaries of medical science and technology. While significant progress has been made in understanding the biology and treatment of cancer. The quest for more effective and targeted therapies remains an on-going endeavour. Hyperthermia, the deliberate application of heat to tissues, has emerged as a promising avenue for enhancing the efficacy of existing treatments, such as radiation therapy and chemotherapy. This thesis, titled "Some Investigations on Patch Antennas for Hyperthermia Applications," delves into the fascinating realm of microstrip antenna design and its application in the realm of hyperthermia therapy for cancer.

Achieving precise and controlled SAR within the target area, while sparing healthy surrounding tissue, is paramount to the success of hyperthermia treatment.

Microstrip antennas are known for their versatility, compactness, and ease of integration into medical devices. They have found application in a myriad of fields, but their potential in hyperthermia for cancer treatment has not been fully explored. This thesis aims to bridge this gap by investigating the design, simulation, and optimization of microstrip antennas for hyperthermia applications. The thesis is divided into six chapters.

Chapter 1 serves as an introductory chapter, providing a comprehensive overview of hyperthermia. It begins by delving into the historical context of hyperthermia, offering insights into its evolution and development. The current state of hyperthermia treatment is explored, showcasing the advancements and challenges within the field. The chapter proceeds to discuss the various classifications of microstrip antennas for hyperthermia, emphasizing their significance based on different parameters. The advantages and disadvantages of utilizing microstrip antennas in hyperthermia applications are carefully examined. By concluding the chapter, the motivation behind the thesis and its objectives are clearly defined and it provides readers with a roadmap for the subsequent chapters.

Chapter 2 presents an extensive literature review focusing on Microstrip Antennas for Industrial, Scientific, and Medical (ISM) and Medical, Implant Communication Service (MICS) bands. It delves into the intricacies of various ISM bands, including the 434 MHz band and the 2.4-2.5 GHz band. By synthesizing information from the literature, Chapter 2 provides a solid foundation for understanding the context and significance of the subsequent chapters. The dielectric properties of phantoms and the associated measurement setup are detailed. Specific Absorption Rate (SAR) theory and its corresponding measurement setup are introduced, offering a fundamental understanding of the key metrics involved.

Chapter 3 introduces a hexagon and a pentagon patch antenna operating at 434 MHz. The antennas feature a planar geometry with ground-loaded slots on the ground plane, serving as loads that influence the input impedance point. A 50-ohm coaxial feed is employed inside the annular ring for power feeding. Simulated and measured results are meticulously discussed and compared, offering a comprehensive evaluation of the antenna's performance. This chapter lays the groundwork for the practical implementation and validation of microstrip antennas.

Chapter 4 showcases an elliptical ISM band antenna operating at 2.48 GHz. Constructed with a dielectric Rogers RT/duroid 5880 copper laminated substrate. The antenna's performance is analyzed in terms of reflection coefficient and Specific Absorption Rate (SAR) in free space. Additionally, the antenna is tested with two different phantoms, (De-ionized) DI water, and (tissue equivalent liquid) TEL. The chapter provides a thorough exploration of the antenna's behaviour and capabilities under various conditions.

Chapter 5 focuses on the design of compact cross-slot and corner-slot microstrip antennas tailored for hyperthermia applications in the ISM band at 2.45 GHz. The achievement of the desired ISM band frequency is explained through the strategic etching of slots along the diagonal axis and from the corners of the square patch. Emphasis is placed on antenna size miniaturization through the manipulation of slot perimeters. This chapter offers valuable insights into the design considerations and performance characteristics of these specialized microstrip antennas.

Chapter 6 serves as the culmination of the work, providing a comprehensive summary of the findings and insights gained throughout the thesis. Conclusions drawn from the experimental and simulation results are presented. The chapter also outlines potential avenues for future research, suggesting ways to enhance and refine microstrip patch antenna designs for hyperthermia applications. This final chapter serves as a guidepost for researchers and practitioners interested in advancing the field of hyperthermia through innovative antenna designs.

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List of Abbreviations

Abbreviation	Details
MICS	Medical implant Communication Service
ISM	Industrial Scientific and Medical
SAR	Specific Absorption Rate
FDTD	Finite Difference Time Domain
MoM	Method of Moment
FEM	Finite Element Method
PEC	Perfect Electric Conductor
HT	Hyperthermia
EBG	Electromagnetic Band Gap
AMC	Artificial Magnetic Conductor
FSS	Frequency Selective Surface
EFS	Effective Field Size
RF	Radio Frequency
DCC	Dual Concentric Conductor
PCB	Printed Circuit Board
UWB	Ultra-Wide Band
VNA	Vector Network Analyzer
TEL	Tissue Equivalent Liquid
DHT	Deep Hyperthermia
MW	Microwave
EM	Electromagnetic
TEM	Transverse Electromagnetic Field