মা আৰু দেউতা,

তোমালোকৰ চৰণত উচ্চর্গা কৰিলো

I dedicate this thesis to my

‘MAA’ and ‘DEUTA’

Preface

Wearable antennas, being at the core of the body centric communication system, has enticed a significant volume of research in the recent decade. These antennas, essentially are characterized by their conformability, compactness, and comfortability. In addition, it is desirable that the antenna's performance is least affected by bending and electrically isolated enough from human body to avoid the mutual adverse effects.

In the present study, a robust wearable antenna is designed and fabricated on a "modified" silicone substrate with improved adherence to copper sheet. The developed substrate exhibited a permittivity of ~2.12 and a loss tangent of ~0.02 at 10 GHz. A simple rectangular microstrip patch antenna designed on the substrate shows reliable performance with consistent minimum gain of 7 dBi, a -10 dB impedance bandwidth > 5.8% and a minimum directivity of 12 dBi when tested on three different bending curvatures. Mitigating the detuning effects of bending is a challenge that has been addressed using a self-compensating type technique without the requirement of any external auxiliary component. The antennas demonstrated a frequency compensation of ≈ 35-50% with trivial effects in the radiation performance. Study of the effect of human body on the antenna performance is carried using in-lab developed numerical and realistic phantoms. The resonating and radiation performance of the antenna is evaluated on phantom of three different sizes as well as for two bending planes which revealed marginal effect on the performance of the developed antenna. The resonant frequency is detuned by a maximum of ~1.5% as compared to the antenna tested in free space along a radiation gain of a minimum 6.6 dBi. The experimental findings are ratified by simulated electric field and surface current analysis. Isolation from the human body through reduction of back radiation is demonstrated by using lossy dielectric shield based on expanded graphite. The shield aid in reduction of penetration electric fields inside the phantom and increasing the front-to-back ratio by a maximum of 76% along with consistent -10 dB impedance bandwidth, directivity and gain.

DECLARATION

I hereby declare that the thesis "***Self-Compensating Compact Wearable Antenna for X-band Communications*** **"**, being submitted to Department of Physics, Tezpur University, Tezpur, Assam in partial fulfillment for the award of the degree of Doctor of Philosophy in Physics, has previously not formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title or recognition.

Date: 14-07-2023 (Revised on 14-02-2024)

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This is to certify that the thesis entitled "***Self-Compensating Compact Wearable Antenna for X-band Communications***", being submitted to Tezpur University in requirement of partial fulfillment for the award of the degree of Doctor of Philosophy in Physics is a record of research work carried out by Mr. Arunav Phukan under my supervision and guidance.

All helps received from various sources have been duly acknowledged. No part of this thesis has been submitted elsewhere for award of any degree.

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"Patience is the road to wisdom….thank you almighty for blessing me with…."

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Arunav Phukan

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List of symbols and abbreviations

σ	Conductivity
T	Surface tension
θ	Theta (angle)
ρ	Mass density
g	Acceleration due to gravity
r	Radius
ε_r	Relative permittivity
ε_r'	Real part of complex permittivity
ε_r''	Imaginary part of complex permittivity
$tan\,\delta$	Dielectric loss tangent
ε_{eff}	Effective permittivity
ε_{rs}	Permittivity of substrate
D_g	Diameter of grooves
e_g	Eccentricity of grooves
f_r	Resonant frequency
Δf_r	Shift in resonant frequency
R_{NF}	Radius of reactive near fields region of antenna
R	Bending radius
B	Inter-groove distance
E	Electric field vector
S_{11}	Scattering parameter (reflection)
GHz	Giga Hertz

MHz	Mega Hertz
m	Meter
cm	Centimeter
mm	Millimeter
µm	Micrometer
nm	Nanometer
Å	Amstrong
A	Ampere
V	Volts
gm	Gram
gm/cc	Gram per centimeter cube
W	Watts
W/kg	Watts per kilogram
dB	Decibel
dBi	Decibels relative to isotropic
BCWC	Body Centric Wireless Communication
WBAN	Wireless Body Area Network
SAR	Specific Absorption Rate
ICNIRP	International Commission on Non-Ionizing Radiation Protection
PLA	Polylactic Acid
PU	Polyurethane
VNA	Vector Network Analyzer
EGl	Ethylene Glycol

NRW	Nicolson Ross Weir
EG	Expanded Graphite
Cu	Copper
SEM	Scanning Electron Microscope
XRD	X-Ray Diffraction
TGA	Thermo-Gravimetric Analysis
TLM	Transmission Line Model
AUT	Antenna Under Test