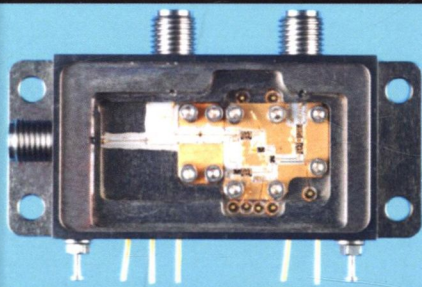
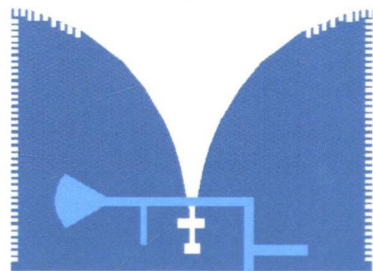
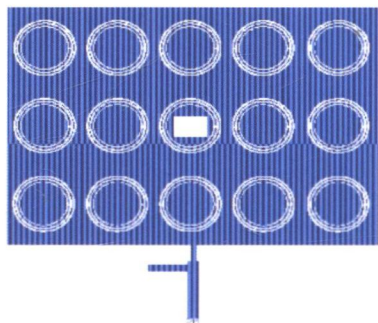
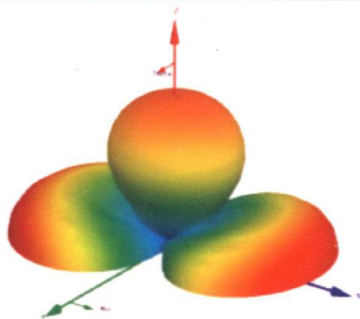


# Novel Wearable Antennas for Communication and Medical Systems

Albert Sabban



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# Novel Wearable Antennas for Communication and Medical Systems

Wearable antennas are meant to be incorporated as part of clothing or placed close to the body. Wearable antennas can be used in countless communication applications including tracking and navigation, medical applications, imaging and detection, RFID, mobile computing and public safety. The book **Novel Wearable Antennas for Communication and Medical Systems** discusses the challenges and technology to develop compact, efficient, wearable antennas. The book begins by presenting elementary communication, electromagnetics and antenna topics needed for engineers and students that do not have a background in design, principles, and features of antennas, printed antennas, wearable antennas, and compact antennas for communication and medical applications. Throughout the book each chapter also covers sufficient mathematical details, physical details and explanations to enable the reader to follow and understand the topics presented. New topics and design methods in the area of wearable antennas, metamaterial antennas, active printed antennas and fractal antennas for communication and medical systems are presented and discussed throughout the book. The book presents computed and measured results in the vicinity of the human body. The book also covers topics such as RF measurement techniques, measurement setups and design considerations. The antennas developed and analyzed in this book were designed and optimized by using 3D full-wave electromagnetics software.

- Discusses technologies and miniaturization techniques in creating efficient small wearable antennas
- Provides elementary electromagnetics and communication basic theory
- Presents mathematical details and physical details with explanations throughout
- Discusses new topics and design methods such as metamaterial antennas, active printed antennas and fractal antennas
- Includes 3D full-wave electromagnetic computation and optimization results

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Sabban

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# Novel Wearable Antennas for Communication and Medical Systems



## *Dedication*

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*This book is dedicated to the memory of my  
father, mother and sister. David Sabban,  
Dolly Sabban and Aliza Sabban*





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# Preface

The main objective of this book is to present new compact wearable antennas for communication and medical systems. Chapter 1 presents the fundamental concepts and applications of wearable communication and medical systems. Chapter 2 presents wearable communication and medical systems electromagnetics and the basic theory and fundamentals of antennas. Chapter 3 presents an introduction to the basic theory for wireless wearable communication system designers. Chapter 4 presents basic antennas for wearable communication systems. Chapter 5 presents wearable printed antennas for wireless communication systems. These chapters are written to assist electrical engineers and students in the study of basic electromagnetic, communication and antenna theory and fundamentals. There are many books on electromagnetic theory and antennas for the electromagnetic scientist. However, there are few books that help electrical engineers and undergraduate students to study and understand basic electromagnetic, communication and antenna theory and fundamentals with few integral and differential equations.

There are several 3D full-wave electromagnetics software products, such as HFSS, ADS, and CST, used to design and analyze communication systems and antennas. Communication systems and antennas developed and analyzed in this book were designed using HFSS and ADS software. For almost all antennas and devices described in this book there was good agreement between computed and measured results. Only one design and fabrication iteration was needed in the development process of the devices and antennas presented in this book.

Wideband wearable antennas for communication and medical applications are presented in Chapter 6. Several wearable antennas are presented in this chapter. Antenna electrical parameters as a function of distance from the human body is discussed in this chapter. Compact wearable radio frequency identification (RFID) antennas are presented in Section 6.8. Chapter 7 presents base station aperture antennas for communication systems. Antenna arrays for wireless communication systems are presented in Section 7.5. An integrated outdoor unit for MM wave satellite communication applications is presented in Section 7.6. A solid state power amplifier (SSPA) is presented in Section 7.7. An integrated Ku band automatic tracking system is presented in Section 7.9.

Novel wearable antennas for wireless communication systems are presented in Chapter 8. New wideband wearable meta-material antennas for communication applications are presented in Section 8.1 through 8.3. Meta-material antenna characteristics in the vicinity of the human body are discussed in Section 8.4. Wearable fractal printed antennas are presented in Sections 8.7 through 8.11. Active wearable printed antennas for medical applications are presented in Chapter 9. Wearable tunable printed antennas for medical applications are presented in Sections 9.1 through 9.8. Active wearable receiving antennas are presented in Section 9.9. An active transmitting antenna is presented in Section 9.10. New wide band passive and active wearable slot and notch antennas for wireless and medical communication systems are presented in Chapter 10.

Microwave and MM wave technologies are presented in Chapter 11. Microwave integrated circuits, monolithic microwave integrated circuits, microelectro-mechanical systems, and low temperature co-fired ceramic technologies are presented in Chapter 11. The main goal of wireless body area networks (BANs) is to continuously provide medical data to physicians.

Design considerations, computational results and measured results of wearable compact transceivers, BANs, are presented in Chapter 12. Wearable systems and antenna measurements are presented in Chapter 13.

Each chapter of the book covers sufficient details to enable students, scientists from all areas, and electrical and biomedical engineers to follow and understand the topics presented in the book. The book begins with the elementary communication, electromagnetics, and antenna topics needed for students and engineers with no background in communication, electromagnetic and antenna theory to study and understand the basic design principles and features of antennas, wearable antennas, printed antennas, and compact antennas for communication and medical applications.

Several topics and designs are presented in this book for the first time. This book may serve students and design engineers as a reference work. It presents new designs in the area of wearable antennas, meta-material antennas, fractal antennas, and active receiving and transmitting antennas. The text contains sufficient mathematical detail and explanations to enable electrical engineering and physics students to understand all topics presented in this book.

Several new wearable antennas are introduced in this book. Design considerations and computed and measured results for the new wearable systems and antennas are presented.

---

# Acknowledgments

Acknowledgements to my family.

My wife Mazal Sabban

My daughters Dolly and Lilach

My son David Sabban

My grandchildren Nooa, Avigail, Ido, Shira, Efrat, Yael Hodaia

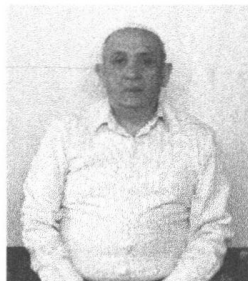
Acknowledgments to my engineering colleagues who helped me through the 39 years of my engineering and research career.





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# About the Author



**Dr. Albert Sabban** received B.Sc and M.Sc degrees Magna Cum Laude in electrical engineering from Tel Aviv University, Israel, in 1976 and 1986, respectively. He received a Ph.D. degree in electrical engineering from University of Colorado at Boulder, USA, in 1991. He also received an MBA degree from Haifa University. His research interests are microwave, antenna engineering, communication systems, biomedical and wearable systems, electromagnetics and system engineering.

From 2010 to date he has been a senior lecturer and researcher at Ort Braude College in Israel in the electrical engineering department. He also leads the communication program at Ort Braude College. Dr. Sabban was an RF and antenna specialist and project leader at hi-tech and biomedical companies. He is an expert in BAN and WBAN systems. He has designed and developed wearable medical systems and antennas for wireless communication systems.

In 1976 he joined the armament development authority, RAFAEL, in Israel. In RAFAEL he worked as a senior researcher, group leader and project leader in the electromagnetic department until 2007. He successfully passed a system engineering course in RAFAEL. During his work at RAFAEL and at other institutes and companies Dr. Sabban gained experience in project management, microwave and system engineering, sales, marketing and training. In 2007 he retired from RAFAEL. From 2008 to 2010 he worked as an RF specialist and project leader at high tech companies. At present he is a senior lecturer and researcher in academic institutes in Israel. He has published over 65 research papers and holds several patents in the antenna area. He has written three books and two chapters in books on microwave and antennas engineering.



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