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## Preface

We live in a fast-paced world today and, very often, we do not even have enough time for ourselves to recuperate fully after suffering from ailments. We also suffer from many lifestyle diseases, inconveniencing us slowly and silently. These are proving to be a big burden to our health care system. Quite naturally, researchers in the health care sector are trying their best to come up with technologies that provide help to those who would like to live a normal life despite their health problems.

Pervasive health care in the area of cardiac abnormalities is perhaps the most important one. One requires constant monitoring of the cardiac condition of a subject who is known to have had difficulties earlier. Holter monitoring had been one of the major steps in this direction, although it is not meant to be a fully wearable yet pervasive system. Over the last decade, attempts are being made to build a device which is truly wearable and provides various pre- and post-processing facilities.

Electrocardiography is the simplest non-invasive method of collecting signal from the beating heart that provides extremely useful information to the doctors. Hence ECG data collection is almost routine in any clinic dealing with heart patients. The procedure is highly standardized and the recorder is well calibrated so that any doctor anywhere in the world can interpret the data. The protocol requires that the patient lies down and be completely immobile so that skin to electrode contact is never disturbed. Any such disturbance will produce spurious signals in the ECG data obliterating the true interpretation by the doctor, making ECG presumably unsuitable for wearable applications.

Efforts have been made to improve the quality of ECG recorders. The weight and size have come down drastically. Data storage and on-chip processing power have improved manifold. The power consumption level has been reduced substantially such that the battery life is now prolonged to several days. The functionality now also includes wireless connectivity among others. All these recent developments make the wearable ECG recorder an ideal candidate for 24×7 monitoring of cardiac patients trying to maintain an active lifestyle.

Notwithstanding above, various types of body movement activities, called BMA in this monograph, continue to plague the usefulness of such recorders due to the motion artifact it generates in the collected ECG data. The skin stretches and contracts due to body movement, changing the contact resistance at the electrode. Any change in skin humidity would also affect the resistivity of the skin but it is not considered in this monograph. The recorded signal is thus very different from the sedentary ECG when the subject is under ambulation. Since the true ECG signal and the motion artifact overlap in the spectrum, it is not possible to filter out these artifacts without affecting the morphology of the ECG signal.

Is pervasive cardiac monitoring using W-ECG recorder at all feasible? This is the key focus of this monograph. Although the industry focus has primarily been in developing such recorders, the signal processing aspects of the corresponding recordings have been mostly overlooked and the corresponding area is still largely unexplored. Needless to say, the final utility of such devices would depend on how useful are these signals to the clinicians.

We observe that most physical activities involve certain repetitive motions of our muscles and hence there must be some structure to the motion artifact signal which is superposed on the true cardiac signal. We ask the question if such a structure can at all be discovered from the recorded ECG signal. If it is so then that particular body movement can be recognized from the recorded ambulatory ECG signal itself. If the structure of the artifact signal is known for a given activity, this should also help us in cleaning the corrupted ECG signal. Further, in order that the above statement makes sense to the clinicians, there has to be some experimental validation that must bring out explicit correlation between this structured noise or artifacts and the actual motion (as measured by some device, say, an accelerometer) of the limb(s). The primary aim of the monograph is to demonstrate through development of appropriate signal processing techniques and experimental procedures that it is, indeed, possible to develop a truly pervasive, W-ECG based, cardiac monitoring system.

As mentioned earlier, the current state of research in this area of ambulatory ECG analysis is still in its infancy. A lot remains to be done before a firm recommendation of the new technology can be made for absorption by the health care industry. This book is meant to initiate the necessary dialog among researchers and practicing engineers to carry the concept further.

Any technical document in the form of a book or a monograph may suffer from the problem of being superfluous and unsubstantiated as there is very little opportunity for complete reviewing by peers. In order to avoid such a problem we made sure that the key concepts are first peer reviewed in the form of publications in appropriate journals. The publications that overlap with the contents of the book are given in the references [99, 100, 101, 102, 103]. We have modified and enhanced them to suit the demand of this book. Needless to say, the copyrights of various figures reproduced from our earlier publications rest with the original publishers.

The book is addressed to a broad audience. It should be useful to both practitioners and researchers in the area of biomedical engineering. We have tried to make the book self-contained and hence there is no specific prerequisite. Any one with basic familiarity with digital signal processing and linear algebra, will find the content quite readable. In order to bridge the gap between hardware and algorithmic developments, we have included chapters that specifically discuss the hardware aspects and the corresponding calibration issues. We have invited our colleagues who have actually developed such a hardware to write a chapter on hardware details. This particular aspect should be specifically useful to the practitioners in technology development.

We hope that the readers will find the book useful. We welcome comments and suggestions from readers.

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*Subhasis Chaudhuri*  
*Tanmay Pawar*  
*Siddhartha Duttagupta*



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Chaudhuri, S.; Pawar, T.D.; Duttagupta, S.

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