

M. Varga, K. Schulz, A. Taschwer and K. J. Wolter, "Towards wireless neural electrodes: System-integration for stimulating and recording of nerve signals," *Proceedings of the 5th Electronics System-integration Technology Conference (ESTC)*, Helsinki, 2014, pp. 1-5.

doi: 10.1109/ESTC.2014.6962805

Abstract: In this paper we present the developed components and the electronic packaging design for a miniaturized, wireless neural electrode. Particularly, the whole system consists of a hook-up electrode for contacting the nerve and an electronic part that generates and sends stimulating signals to the nerve and records the neural signals. The hook-up electrode has been designed in a way that enhances the easy of positioning during the medical procedure and consists of biocompatible materials in order to avoid toxic tissue reactions. The most important component of the electronic part is a developed ASIC, which receives power and data from a coil and generates the stimulating signals and records signals coming from the nerve. The telemetric power and data transmission is based on a transponder principle. A separate sending and reading unit laid under the patient is providing energy and data transmission to the wireless system for stimulation and recording. The assembly of all components is ensured by a system-integration approach that maintains functioning of the whole wireless system properly and reliably. In this regard, the proposed wireless neural electrode offers a promising alternative for applications in neural electrical stimulation and recording.

keywords: {application specific integrated circuits;bioelectric phenomena;biological tissues;biomedical electrodes;data communication;medical signal processing;neurophysiology;packaging;ASIC;biocompatible materials;data transmission;electronic packaging design;hook-up electrode;nerve signal recording;nerve signal stimulation;neural electrical recording;neural electrical stimulation;system-integration;system-integration approach;telemetric power transmission;toxic tissue reactions;transponder principle;wireless neural electrodes;wireless system;Application specific integrated circuits;Coils;Communication system security;Electrodes;Receivers;Wireless communication;Wireless sensor networks},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6962805&isnumber=6962707>

G. Crifaci *et al.*, "ECG and GSR measure and analysis using wearable systems: Application in anorexia nervosa adolescents," *2013 8th International Symposium on Image and Signal Processing and Analysis (ISPA)*, Trieste, 2013, pp. 499-504.

doi: 10.1109/ISPA.2013.6703792

Abstract: The objective of this study was to test the feasibility of using wearable sensors and wireless technology to measure the autonomic function and stress level in the ambulatory setting. Autonomic function was studied acquiring ECG tracings by means of a wearable sensorized chest strap. Galvanic skin response (GSR) was measured as an indicator of stress level by two electrodes positioned on the palm of the non dominant hand and a wireless acquisition module in a wrist support. Data were acquired in a group of young adolescents with anorexia nervosa (AN) as compared to controls in resting conditions. From ECG the tachogram, the mean RR intervals (meanRR), the root mean square of successive differences (RMSSD) the power of low frequency (LF) and high frequency (HF) bands and the LF/HF ratio were assessed. From GSR mean, median, variance, standard deviation, area under the curve of the sampled signal and delta between maximum and minimum conductance values were computed. All AN patients showed reduced HR and increased meanRR and RMSSD. HF increase, LF decrease and LF/HF reduction were suggestive of prevalence of parasympathetic over sympathetic activity. Additionally, AN showed a decreased GSR variance, standard deviation and delta value with respect to controls. The results of this study show that wearable sensors used in this study were feasible, unobtrusive and therefore extremely suitable for young patients providing the means for future monitoring in the home setting which may be preferable in this population burdened by high cardiovascular morbidity and mortality.

keywords: {biomedical communication;electrocardiography;least mean squares methods;medical signal processing;patient monitoring;sensors;AN patients;ECG tracings;GSR;LF-HF ratio;RMSSD;ambulatory setting;anorexia nervosa adolescents;autonomic function;cardiovascular morbidity;cardiovascular mortality;galvanic skin response;high frequency bands;home setting;low frequency bands;mean RR intervals;meanRR;nondominant hand;parasympathetic activity;root mean square of successive differences;sampld signal;standard deviation;stress level;sympathetic activity;tachogram;wearable sensorized chest strap;wearable sensors;wearable systems;wireless acquisition module;wireless technology;wrist support;young patients;Biomedical monitoring;Electrocardiography;Heart rate variability;Monitoring;Resonant frequency;Skin;eating disorders;galvanic skin response;heart rate variability;wearable sensors},

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I. Tomašić, S. Frljak and R. Trobec, "Estimating the Universal Positions of Wireless Body Electrodes for Measuring Cardiac Electrical Activity," in *IEEE Transactions on Biomedical Engineering*, vol. 60, no. 12, pp. 3368-3374, Dec. 2013.

doi: 10.1109/TBME.2013.2276291

Abstract: A methodology is presented for estimating the wireless body electrode (WE) positions and for calculating the linear transformations that enable the synthesis of a 12-lead ECG or a multichannel ECG from three WEs, which in turn simplifies and improves the acquisition of ECGs. We present, compare, and evaluate three approaches to the synthesis: fully personalized, fully universal, and combined with universal leads and personalized transformations. The evaluation results show that WEs are an acceptable alternative to the standard 12-lead ECG device for patients with chronic myocardial ischemia, if either the fully personalized or combined approach is used. The median correlation coefficients are all higher than 0.94 and 0.92 for the fully personalized and combined approaches, respectively. The corresponding kappa and percentual diagnostic agreements between the synthesized and target 12-lead ECGs are 0.88 (95%) and 0.83 (92%), respectively. The evaluation additionally shows that the personalization of the transformations has more impact on the quality of the synthesized ECGs than the personalization of the WEs' positions.

keywords: {biomedical electrodes;body sensor networks;electrocardiography;cardiac electrical activity;linear transformation;multichannel ECG;personalized transformation;universal position;wireless body electrodes;Electrocardiography;Electrodes;Position measurement;Standards;Surgery;Visualization;Wireless communication;Derived electrocardiograms;ECG synthesis;differential leads;electrocardiography;wireless electrodes;0},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6574211&isnumber=6670086>

K. Hung, C. C. Lee, W. M. Chan, S. O. Choy and P. Kwok, "Development of a wearable system integrated with novel biomedical sensors for ubiquitous healthcare," *2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, San Diego, CA, 2012, pp. 5802-5805.

doi: 10.1109/EMBC.2012.6347313

Abstract: The world's ageing population has led to an urgent need for long-term and patient-centered healthcare solutions. Hence, there is a growing need for wearable systems for physiologic monitoring. While various biosignals are monitored with traditional approaches, it is worthwhile to investigate alternative sensing techniques in order to improve accessibility and understanding of patients' conditions.

This paper presents our laboratory's development of such a wearable system, which makes use of unconventional techniques for physiologic monitoring. With its integrated textile electrocardiogram (ECG) electrodes, intelligent finger-ring photoplethysmogram (PPG) sensor, miniaturized optical fiber-based temperature sensor, eye dynamics monitor, global positioning system (GPS) module, and wireless capability, it demonstrates a feasible solution for ubiquitous healthcare.

keywords: {Global Positioning System;biomedical electrodes;biomedical optical imaging;biothermics;electrocardiography;eye;fibre optic sensors;geriatrics;health care;medical computing;neurophysiology;patient monitoring;personal area networks;physiological models;temperature sensors;textiles;ubiquitous computing;wearable computers;wireless sensor networks;GPS module;ageing population;biomedical sensors;eye dynamics monitor;global positioning system module;intelligent finger-ring photoplethysmogram PPG sensor;optical fiber-based temperature sensor;patient-centered healthcare solutions;textile ECG electrodes;textile electrocardiogram electrodes;ubiquitous healthcare;wearable system;wireless capability;Biomedical monitoring;Electrocardiography;Medical services;Monitoring;Sociology;Temperature measurement;Temperature sensors;Biosensing Techniques;Humans;Monitoring, Physiologic;Ocular Physiological Phenomena;Radio Waves;Systems Integration;Temperature},

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H. Cao, H. Li, L. Stocco and V. C. M. Leung, "Wireless three-pad ECG system: Challenges, design, and evaluations," in *Journal of Communications and Networks*, vol. 13, no. 2, pp. 113-124, April 2011.

doi: 10.1109/JCN.2011.6157410

Abstract: Electrocardiography (ECG) is a widely accepted approach for monitoring of cardiac activity and clinical diagnosis of heart diseases. Since cardiologists have been well-trained to accept 12-lead ECG information, a huge number of ECG systems are using such number of electrodes and placement configuration to facilitate fast interpretation. Our goal is to design a wireless ECG system which renders conventional 12-lead ECG information. We propose the three-pad ECG system (W3ECG). W3ECG furthers the pad design idea of the single-pad approach. Signals obtained from these three pads, plus their placement information, make it possible to synthesize conventional 12-lead ECG signals. We provide one example of pad placement and evaluate its performance by examining ECG data of four patients available from online database. Feasibility test of our selected pad placement positions show comparable results with respect to the EASI lead system. Experimental results also exhibit high correlations between synthesized and directly observed 12-lead signals (9 out of 12 cross-correlation coefficients higher than 0.75).

keywords: {biomedical electrodes;diseases;electrocardiography;health care;information retrieval systems;information services;patient diagnosis;patient monitoring;telemedicine;cardiac activity monitoring;clinical diagnosis;cross-correlation coefficients;electrocardiography;electrodes;heart diseases;mobile health care;online database;placement configuration;wireless three-pad ECG system;Electric potential;Electrocardiography;Electrodes;Heart;Lead;Vectors;Wireless communication;12-lead transformation;electrocardiography (ECG);mobile healthcare},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6157410&isnumber=6157403>

R. Trobec and I. Tomašić, "Synthesis of the 12-Lead Electrocardiogram From Differential Leads," in *IEEE Transactions on Information Technology in Biomedicine*, vol. 15, no. 4, pp. 615-621, July 2011.

doi: 10.1109/TITB.2011.2159236

Abstract: A new approach is proposed for synthesizing the standard 12-lead ECG from three differential leads formed by pairs of proximal electrodes on the body surface. The method is supported by a statistical analysis that gives the best personalized positions of electrodes. The measurements from multichannel ECGs were used to calculate the differential leads. Our algorithm searches for optimal differential leads and the corresponding personalized transformation matrix that is used to synthesize the standard 12-lead ECG. The algorithm has been evaluated on 99 multichannel ECGs measured on 30 healthy subjects and 35 patients scheduled for elective cardiac surgery. It is shown that the algorithm significantly outperforms the synthesis based on the EASI lead system with medians of correlation coefficients greater than 0.954 for all 12 standard leads. To determine the optimal number of differential leads, the syntheses for two, three, and four differential leads were calculated. The analysis shows that 3 is the optimal number of differential leads for practical applications. Because of the proximity of the differential electrodes, the proposed approach offers an opportunity for the synthesis of a standard 12-lead ECG with wireless electrodes.

keywords: {biomedical electrodes;electrocardiography;medical signal processing;signal synthesis;statistical analysis;surgery;12-lead ECG;differential leads;elective cardiac surgery;electrocardiogram;personalized positions;personalized transformation matrix;proximal electrodes;statistical analysis;wireless electrodes;Biomedical measurements;Electrocardiography;Electrodes;Heart;Lead;Position measurement;Surgery;Derived ECGs;ECG synthesis;differential leads (DLs);electrocardiography;wireless electrodes (WEs);Adult;Aged;Algorithms;Cardiac Surgical Procedures;Case-Control Studies;Electrocardiography;Electrodes;Female;Humans;Male;Middle Aged;Signal Processing, Computer-Assisted;Surgical Procedures, Elective},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5954048&isnumber=5954041>

I. J. Wang *et al.*, "A Wearable Mobile Electrocardiogram measurement device with novel dry polymer-based electrodes," *TENCON 2010 - 2010 IEEE Region 10 Conference*, Fukuoka, 2010, pp. 379-384.

doi: 10.1109/TENCON.2010.5686658

Abstract: A Wearable Mobile Electrocardiogram Monitoring System (WMEMS), which mainly consists of a wearable Electrocardiogram (ECG) acquisition device, a mobile phone with global positioning system, and a healthcare server, was developed in this study. Most of telemedicine systems for long-term ECG monitoring focus on the application of communication techniques. However, how to monitor long-term ECG state more comfortably in daily life is also an important issue. In this study, a novel dry foam electrode was designed and applied for the wearable ECG acquisition device in our WMEMS. These novel dry foam electrodes without conduction gels can provide good conductivity to acquire ECG signal effectively, and can adapt to irregular skin surface to maintain low skin-electrode impedance and reduce motion artifacts under movement. Therefore, the wearable ECG acquisition device is suitable for long-term ECG monitoring in daily life. Moreover, by combining with wireless communication technique, our WMEMS can monitor patient's heart rate continuously anywhere in the globe if they are under the coverage of GSM cellular network. Experiment results showed that our WMEMS really provides a good system prototype for ECG telemedicine applications.

keywords: {Global Positioning System;biomedical electrodes;biomedical equipment;biomedical measurement;biomedical telemetry;cellular radio;electrocardiography;medical computing;medical information systems;skin;telemedicine;ECG monitoring;ECG signal;GSM cellular network;communication techniques;conduction gels;dry foam electrode;dry polymer-based electrodes;global positioning system;healthcare server;low skin-electrode impedance;mobile phone;reduce motion artifacts;skin surface;telemedicine

system;wearable ECG acquisition device;wearable mobile electrocardiogram measurement device;wearable mobile electrocardiogram monitoring system;wireless communication technique;Atrial fibrillation Telemedicine;Dry foam electrode;ECG},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5686658&isnumber=5685837>

N. V. Rivera, S. Venkatesh, C. Anderson and R. M. Buehrer, "Multi-target estimation of heart and respiration rates using ultra wideband sensors," *2006 14th European Signal Processing Conference*, Florence, 2006, pp. 1-6.

Abstract: Vital-signs monitoring devices continue to utilize invasive sensing methodologies, ranging from skin surface contact techniques such as the use of electrodes for measuring cardiac signals (ECG test), to more intrusive techniques such as the utilization of a facial mask for measuring gas exchange during respiration. In this paper, we present a wireless radar technique based on ultra-wideband (UWB) technology for non-invasive monitoring of heart and respiration rates. Our technique is based on the detection of chest-cavity motion through the measurement of UWB signal displacements due to this motion. We show that the technique provides accurate results even in the presence of multiple subjects. Specifically, we investigate the two techniques for estimating breathing and heart rates in the presence of multiple subjects: (1) the use of clustering algorithms to isolate the combined position and breathing/heart rate of multiple subjects and (2) the use of MUSIC to accurately estimate only the rates. Results are based on measurements from experiments with multiple subjects in a laboratory setting.

keywords: {biomedical equipment;electrocardiography;medical signal detection;patient monitoring;pattern clustering;pneumodynamics;radar detection;radar signal processing;skin;ultra wideband radar;wireless sensor networks;ECG test;UWB signal displacements;breathing-heart rate;cardiac signals;chest-cavity motion detection;clustering algorithms;gas exchange;invasive sensing methodologies;multitarget estimation;noninvasive monitoring;respiration rates;skin surface contact techniques;ultrawideband sensors;vital-sign monitoring devices;wireless radar technique;Biomedical monitoring;Blood;Estimation;Heart rate;Lungs;Monitoring},
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C. H. Hsu and S. H. Wu, "Robust signal synthesis of the 12-lead ECG using 3-Lead wireless ECG systems," *2014 IEEE International Conference on Communications (ICC)*, Sydney, NSW, 2014, pp. 3517-3522.

doi: 10.1109/ICC.2014.6883866

Abstract: A new signal synthesis and tracking method is developed for a 3-Lead wireless electrocardiography (ECG) system. Exploiting the temporal correlations in ECG signals, the standard 12-lead ECG signals can be synthesized with high precision by using only three differential pairs of electrodes. The correlations between the original and synthesized ECG leads can be as high as 0.98. And the separation between the two electrodes of a pair can be drastically reduced to around 10 cm, which is about the size of a medium adhesive tape. Experiment results also show that the proposed ECG synthesis method is much more robust to variations in acquisition positions when taking into account the spatial correlations among the ECG leads in syntheses. This greatly improves the feasibility of using fully wireless ECG systems on the long-term monitoring and diagnosis of heart diseases.

keywords: {correlation methods;electrocardiography;medical signal processing;patient diagnosis;patient monitoring;3-lead wireless ECG systems;3-lead wireless electrocardiography system;ECG leads;ECG synthesis method;acquisition positions;fully wireless ECG systems;heart disease diagnosis;long-term heart disease monitoring;robust signal synthesis;signal tracking method;spatial correlations;standard 12-lead ECG signals;temporal correlations;Cardiac arrest;Correlation;Electrocardiography;Electrodes;Standards;Wireless communication;Wireless sensor networks},
URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6883866&isnumber=6883277>

R. Issac and M. S. Ajaynath, "CUEDETA:A real time heart monitoring system using android smartphone," *2012 Annual IEEE India Conference (INDICON)*, Kochi, 2012, pp. 047-052.

doi: 10.1109/INDCON.2012.6420587

Abstract: According to WHO(World Health Organization), estimated about 17 million people die around the world due to cardio vascular diseases, particularly heart attack, in them most of the deaths are due to untimely intervention. If proper medical care can be given to the patients at the right time their lives can be saved, for that all we need is a system that continuously monitors ones ECG signal, so we have introduced a system called CUEDETA. The name CUEDETA comes from the word cuerpo which means human body and detalles which means details. This system will continuously monitors the ECG signals of the patient and send alerts to his/her contacts, medical professional and ambulance services. The alert also includes a URL which can be used to find the exact position of the patient using Google maps. The alerts are propagated in a arranged fashion, so that the patient and his/her social contacts have a chance to detect false alerts before contacting medical professionals, this is possible by connecting wireless heart rate monitoring device to the body and interfacing it with a smart phone. Here the software frame work is developed in android to support diverse class of mobile devices.

keywords: {biomedical equipment;cardiovascular system;diseases;electrocardiography;medical signal processing;patient care;patient monitoring;smart phones;CUEDETA;ECG signal;Google maps;URL;WHO;World Health Organization;android smartphone;cardiovascular diseases;heart attack;heart monitoring system;human body;medical care;mobile devices;patient care;social contacts;software framework;wireless heart rate monitoring device;Blood;Bluetooth;Electrocardiography;Electrodes;Heart;Microcontrollers;Monitoring;Smart phone;alert;cuedeta;heart attack},
URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6420587&isnumber=6420575>

H. W. Noh, Y. Jang, I. B. Lee, Y. Song, J. W. Jeong and S. Lee, "A preliminary study of the effect of electrode placement in order to define a suitable location for two electrodes and obtain sufficiently reliable ECG signals when monitoring with wireless system," *2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, San Diego, CA, 2012, pp. 2124-2127.

doi: 10.1109/EMBC.2012.6346380

Abstract: Most countries face high and increasing rates of cardiovascular disease. Each year, heart disease kills more Americans than cancer. Therefore, there has been a promising market for portable ECG equipment and it is increasing. To use portable ECG measuring devices, it is essential to define a suitable location for the measuring as we need to reduced electrode size and distance. This research proposes to study how the inter-electrode distance affects the signal and how the electrode pair should be placed on the chest in order to obtain a sufficiently reliable ECG signal to detect heart arrhythmias in any environment, such as home or work. Therefore, we developed a compact, portable patch type ambulatory ECG monitoring system, Heart Tracker, using a microprocessor for preliminary study of signal analysis. To optimize the electrode arrangement in wireless environment, we compared HT and standard 12 lead with changing electrode position.

keywords: {biomedical electrodes;cardiovascular system;diseases;electrocardiography;medical signal processing;microcomputer applications;patient monitoring;portable instruments;Heart Tracker;ambulatory ECG monitoring system;cardiovascular

disease;chest;electrode arrangement;electrode location;electrode placement;electrode position;electrode size;heart arrhythmias;heart disease;inter-electrode distance;microprocessor;portable ECG equipment;portable ECG measuring devices;reliable ECG signals;signal analysis;wireless system monitoring;Bluetooth;Electrocardiography;Electrodes;Heart;Monitoring;Standards;Wireless communication;Algorithms;Diagnosis, Computer-Assisted;Electrocardiography, Ambulatory;Electrodes;Equipment Design;Equipment Failure Analysis;Humans;Pilot Projects;Reproducibility of Results;Sensitivity and Specificity;Signal Processing, Computer-Assisted;Telemetry},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6346380&isnumber=6345844>

D. Vukajlovic *et al.*, "Wireless monitoring of reconstructed 12-lead ECG in atrial fibrillation patients enables differential diagnosis of recurrent arrhythmias," *2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Boston, MA, 2011, pp. 4741-4744.

doi: 10.1109/IEMBS.2011.6091174

Abstract: Differential diagnosis of symptomatic events in post-ablation atrial fibrillation (AF) patients (pts) is important; in particular, accurate, reliable detection of AF or atrial flutter (AFL) is essential. However, existing remote monitoring devices usually require attached leads and are not suitable for prolonged monitoring; moreover, most do not provide sufficient information to assess atrial activity, since they generally monitor only 1-3 ECG leads and rely on RR interval variability for AF diagnosis. A new hand-held, wireless, symptom-activated event monitor (CardioBip; CB) does not require attached leads and hence can be conveniently used for extended periods. Moreover, CB provides data that enables remote reconstruction of full 12-lead ECG data including atrial signal information. We hypothesized that these CB features would enable accurate remote differential diagnosis of symptomatic arrhythmias in post-ablation AF pts. Methods: 21 pts who underwent catheter ablation for AF were instructed to make a CB transmission (TX) whenever palpitations, lightheadedness, or similar symptoms occurred, and at multiple times daily when asymptomatic, during a 60 day post-ablation time period. CB transmissions (TXs) were analyzed blindly by 2 expert readers, with differences adjudicated by consensus. Results: 7 pts had no symptomatic episodes during the monitoring period. 14 of 21 pts had symptomatic events and made a total of 1699 TX, 164 of which were during symptoms. TX quality was acceptable for rhythm diagnosis and atrial activity in 96%. 118 TX from 10 symptomatic pts showed AF (96 TX from 10 pts) or AFL (22 TX from 3 pts), and 46 TX from 9 pts showed frequent PACs or PVCs. No other arrhythmias were detected. Five pts made symptomatic TX during AF/AFL and also during PACs/PVCs. Conclusions: Use of CB during symptomatic episodes enabled detection and differential diagnosis of symptomatic arrhythmias. The ability of CB to provide accurate reconstruction of 12 L ECGs including atrial activity, combined with its ease of use, makes it suitable for long-term surveillance for recurrent AF in post-ablation patients.

keywords: {catheters;electrocardiography;medical disorders;medical signal processing;patient diagnosis;patient monitoring;signal reconstruction;CB transmission;RR interval variability;atrial activity;atrial flutter;catheter ablation;differential diagnosis;handheld wireless symptom-activated event monitor;lightheadedness;long-term surveillance;palpitations;post-ablation atrial fibrillation;prolonged monitoring;reconstructed 12-lead ECG;recurrent arrhythmias;remote monitoring devices;rhythm diagnosis;symptomatic events;wireless monitoring;Atrial fibrillation;Catheters;Electrocardiography;Electrodes;Remote monitoring;Wireless communication;Atrial Fibrillation;Cardiac Monitoring;Electrocardiography;Remote;Wireless;Adult;Aged;Arrhythmias, Cardiac;Atrial Fibrillation;Diagnosis, Differential;Electrocardiography;Humans;Middle Aged;Radio Waves},

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E. Sardini, M. Serpelloni and M. Ometto, "Multi-parameters wireless shirt for physiological monitoring," *2011 IEEE International Symposium on Medical Measurements and Applications*, Bari, 2011, pp. 316-321.

doi: 10.1109/MeMeA.2011.5966654

Abstract: The ability to monitor the health status of elderly patients or patients undergoing home therapy allows significant advantages in terms of cost and convenience of the subject. However, these non-clinical applications of biomedical signals acquisition require different monitoring devices having, between the other characteristics, reduced size, low power and environment compatibility. The research activity concerns the development of a new wearable device that can monitor the main physiological parameters of a person in a non-invasive manner. All sensors have contactless characteristics that permit to avoid the direct contact with the skin. This system is a useful solution for monitoring the health condition of patients at home. The wearable monitoring system consists of two subsystems: first, a wearable data acquisition hardware, in which the sensors are integrated for the acquisition of biomedical parameters, and secondly, a remote monitoring station located separately and connected to the Internet for telemedicine applications. The physiological parameters that are monitored are electrocardiogram (ECG), heart rate (HR), derived from ECG signals through the determination of RR intervals, respiratory rate, and three-axis motion (acceleration and position) of the subject measured using an accelerometer. All sensors are designed using contactless measurement techniques, thus avoiding the use of gel for the conduction of the signal and possible skin irritation due to contact. The electrodes for measuring ECG signal are capacitive, while the measure of respiration is obtained by plethysmography, which does not require direct contact with skin. In order to design and construct the signal acquisition circuits in an efficient and simple manner, modular design concept is adopted in this research. The flexible signal conditioning modules are designed and assembled together. The human parameters can be recorded and analyzed continuously during work activities at home. The correct evaluation of these parameters allows the medical staff to assess to the state of health, to know accidental injury or other danger occurred in patients at home.

keywords: {acceleration measurement;biomechanics;biomedical telemetry;body area networks;body sensor networks;electrocardiography;injuries;internetworking;medical signal detection;medical signal processing;patient monitoring;plethysmography;pneumodynamics;prosthetics;remote sensing;signal processing equipment;telemedicine;ECG;acceleration measurement;accelerometers;accidental injury;biomedical signals acquisition;contactless sensors;electrocardiogram;health status monitoring;heart rate;integrated sensors;internet network;multiparameter wireless shirt;physiological monitoring;plethysmography;remote monitoring station;respiratory rate;signal acquisition circuit design;telemedicine application;three-axis motion;wearable data acquisition hardware;wearable device;Acceleration;Accelerometers;Biomedical monitoring;Electrocardiography;Electrodes;Monitoring;Sensors;Body measurement;Capacitive electrodes;Cardiorespiratory signal measuring;Electrocardiography (ECG);Heartbeat;Home healthcare;Respiratory cycle;Wearable sensor;contactless measurements},

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J. Yoo, L. Yan, S. Lee, Y. Kim and H. J. Yoo, "A 5.2 mW Self-Configured Wearable Body Sensor Network Controller and a 12 μ W Wirelessly Powered Sensor for a Continuous Health Monitoring System," in *IEEE Journal of Solid-State Circuits*, vol. 45, no. 1, pp. 178-188, Jan. 2010.

doi: 10.1109/JSSC.2009.2034440

Abstract: A self-configured body sensor network controller and a high efficiency wirelessly powered sensor are presented for a wearable, continuous health monitoring system. The sensor chip harvests its power from the surrounding health monitoring band using an Adaptive Threshold Rectifier (ATR) with 54.9% efficiency, and it consumes 12 μ W to implement an electrocardiogram (ECG) analog front-end and an ADC. The ATR is implemented with a standard CMOS process for low cost. The adhesive bandage type sensor patch is composed of the sensor chip, a Planar-Fashionable Circuit Board (P-FCB) inductor, and a pair of dry P-FCB electrodes. The dry P-FCB electrodes enable long term monitoring without skin irritation. The network controller automatically locates the sensor position, configures the sensor type (self-configuration), wirelessly provides power to the configured sensors, and transacts data with only the selected sensors while dissipating 5.2 mW at a single 1.8 V supply. Both the sensor and the health monitoring band are implemented using P-FCB for enhanced wearability and for lower production cost. The sensor chip and the network controller chip occupy 4.8 mm² and 15.0 mm², respectively, including pads, in standard 0.18 μ m 1P6M CMOS technology.

keywords: {CMOS integrated circuits;analogue-digital conversion;biomedical electronics;body sensor networks;electrocardiography;energy harvesting;health care;patient monitoring;power supplies to apparatus;rectifiers;ADC;CMOS process;CMOS technology;ECG analog front end;P-FCB inductor;adaptive threshold rectifier;adhesive bandage type sensor patch;body sensor network controller;continuous health monitoring system;dry P-FCB electrodes;electrocardiogram;energy harvesting;health monitoring band;long term monitoring;planar fashionable circuit board inductor;power 12 μ W;power 5.2 mW;self configured wearable BSN controller;sensor chip;size 15.0 mm;size 4.8 mm;voltage 1.8 V;wirelessly powered sensor;Biomedical monitoring;Body sensor networks;CMOS technology;Control systems;Costs;Electrocardiography;Electrodes;Rectifiers;Sensor systems;Wearable sensors;Body sensor network;continuous health monitoring;dry electrode;electrocardiogram (ECG);planar-fashionable circuit board (P-FCB);rectifier;self-configuration;wearable network;wireless power transmission},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5357569&isnumber=5357544>

F. Chen, H. Wu, P. L. Hsu, B. Stronger, R. Sheridan and H. Ma, "SmartPad: A wireless, adhesive-electrode-free, autonomous ECG acquisition system," *2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Vancouver, BC, 2008, pp. 2345-2348.

doi: 10.1109/IEMBS.2008.4649669

Abstract: During medical procedures, such as surgery, a patient's vital signs are typically monitored using a web of wires connected to adhesive electrodes. The large number of wires inhibits the medical team's access to the patient while the adhesive electrodes can detach, fail, or be out-of-stock, causing delays in the procedure. In order to combat these problems, we have developed the SmartPad: a system that displays a patient's electrocardiogram (ECG) signal without adhesive pads, wires, or active intervention from a clinician. The system automatically selects three electrodes from an array of Cu/Ni-fabric based electrodes patterned on a thin pad on which the patient lies. The selected electrodes are used to provide a differential 3-lead measurement of the patient's ECG, which is then transmitted wirelessly and displayed on a laptop computer.

keywords: {Biomedical electrodes;Biomedical monitoring;Condition monitoring;Delay;Displays;Electrocardiography;Patient monitoring;Portable computers;Surgery;Wires;Algorithms;Electrocardiography;Electrodes;Equipment Design;Humans;Prone Position;Signal Processing, Computer-Assisted;Supine Position;Telemetry},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4649669&isnumber=4649055>

Y. Fukuoka, T. F. Oostendorp, R. J. Cohen and A. A. Armoundas, "A simulation study on a catheter navigation method for guiding the ablative therapy of cardiac arrhythmias," *2001 Conference Proceedings of the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 2001, pp. 402-404 vol.1.

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Abstract: We investigated the ability of a computer algorithm to guide the ablative therapy of cardiac arrhythmias. Specifically, in computer simulations we examined the accuracy of this algorithm to guide the tip of the ablation catheter to the site of the origin of the arrhythmias. We model both the ECG corresponding site of the origin of the arrhythmia and current pulses generated from a pair of electrodes at the tip of the ablation catheter with a single equivalent moving dipole (SEMD). In the forward problem we employed a realistic anatomic geometry torso model. In the inverse problem we used the SEMD model in an infinite homogeneous volume conductor. The results of this investigation suggest that the bounded, heterogeneous volume conductor introduces systematic error in the estimated compared to the true dipole position. However, we found that the systematic error had minor influence in the ability of the algorithm to accurately guide the tip of the ablation catheter to the site of the origin of the arrhythmia.

keywords: {digital simulation;electrocardiography;inverse problems;medical computing;navigation;patient treatment;physiological models;ECG modeling;ablation catheter tip guidance;algorithm accuracy;computer simulations;forward problem;heterogeneous volume conductor;realistic anatomic geometry torso model;single equivalent moving dipole;systematic error>true dipole position;Catheters;Computational modeling;Computer simulation;Conductors;Electrocardiography;Electrodes;Geometry;Medical treatment;Navigation;Pulse generation},

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