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RESEARCH ARTICLE

Heart Rate Monitoring using Injection Locked PLL Resonator and Microcontroller

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Abstract

Monitoring vital patient signs using pulse rate, with integration of technology for better future. Phase Locked Loop (PLL) device is combined with embedded wrist for measuring heart rate for stabilized values. Depending on readings in accordance with predefined values, if there is difference in value then ADC and microcontroller is used for RF(radio frequency) sensors to activate for encryption and decryption of information to small devices like mobiles. Mostly heart attacks are caused during sleep in night time. Monitoring heart during sleep and before sleep, after sleep is essential. The sensor is kept 0.3 to 1 mm distance from the skin near carpus under the clothes made of fabric of cotton. The pulse of wrist is taken to a portable piezo-electric transducer. These are taken for further values and messages to phone are used using GSM and Bluetooth. *Index Terms*— heart rate, radio frequency, sleep, wearable sensors, wrist pulse, Internet of things, GSM, Bluetooth.

I.Introduction

Heart rate monitoring is one of the contemporaneous generation challenges for many professionals and doctors. Cardiovascular diseases are one of peculiar diseases which are caused by health problems and obesity [1]. Mostly these problems occur in middle age and old age group. With increase in population the continuous monitoring of health for physiological conditions and diseases becomes difficult. To reduce them a portable device like watch is used as sensor (e.g. Galaxy Gear, G Watch R, Apple watch)[2]. Heart rate is normally measured by pulse readings for minute on hand. It can also be measured on a beat-to-beat based on the combined effects of the heart, brain and some of cranial nervous systems. Depending on state of body and mind the heart rate varies .Heart Rate Variability (HRV) mostly depends on the situations occurring on the mind which causes hyperactive state or depression state. Both of these are highly responsible for variations which may cause heart attack.[3] Sometimes due to excessive stress levels and physical exercises it may occur. These are naturally accompanied by a lower oxygen in the blood saturation and of airflow for at least 10 s, which results in decrease of heart rate. This HRV may be a good differentiator for causes of heart attacks and levels of severity in them.[4]Several physiological methods have been widely used to sense and measure heart rate, like electrocardiography (ECG),magnetic resonance imaging(MRI),impedance plethysmography, ballisto cardiography, as well as piezo-electrography.[5]As these methods use electrode-based sensors on the skin surface which are costly and cause side effects, if they are used in long-term. To decrease them we are now moving to mobility devices with combination of wireless sensor networks for good transmission reliability. Over recent years the more usage of spectrum caused the different ion in usage of bandwidths for any sensor.RF sensor mainly uses Radio Frequency range which can cover a good distance for transmission to far places in emergencies, which has to be directly contacted and Bluetooth for nearby range for a patients mobile.[6]In addition patients are monitored for changes in heart rate electroencephalogram (EEG), ECG, chin electromyogram, respiration, and pulse oximetry is noted.[7]By this we can analyse the activities of patient for cause of heart attack and the possibilities to reduce it based on results. From the previous research, the Doppler radar of continuous wave which is functioning in far field at 2.4 GHz or ten GHz will discover heart rates at a distance of around a hundred cm far from the chest. Ordinarily we'll check pulse close to right arm for simple identification.[8] But, the signal output of the system is principally full of motion artifacts; the obtained heart beat signal will be glorious by frequent body movements attributable to nature of the Christian Johann Doppler radio detection and ranging. Considering this drawback, we've taken completely different approach to live the guts rate for terribly short distances (about two to five cm) far from the chest that permits the device to be embedded into consumer goods or a blanket. Our devices discover pulse rate supported a contact sensing methodology within the close to field.[9]we've conjointly applied AN RF detector with a transmitter and receiver antenna for causing info to mobile or watch to discover gliding joint pulse (i.e. the heartbeat of the radial or arm bone artery).A .Doppler radio detection and ranging within the way field Detection of important sign exploitation Christian Johann Doppler radio detection and ranging is recently studied as a technique for sleuthing the heartbeat and life sign of someone gift behind a block wall or buried underground (e.g. AN X-band life-detection system). Early 2000'sshowstudies for homecare systems that specialize in sensing life signals by exploitation Christian Johann Doppler radio detection and ranging at2.4 GHz that use industrial, scientific for the medical purpose in the bands.[10]

In past 20 years different Christian Johann Doppler radio detection and ranging contact sign detection schemes are determined underneath completely different environments for various applications.[11] an important drawback that blockaded these technologies from wide used is that the noise made by fast body motion. for instance, once the radio detection and ranging has been used nightlong for sleep observance in an exceedingly scientific atmosphere, the sign detected are stopped when the subject under test rolls over on the bed, producing a false alarm.[12]B.RF sensor in the near field A frequency (RF) sensing element is employed to live the close to field impact employing a 1-port resonator settled in proximity to somebody's chest.[13]It will notice the amendment in section of reflection constant employing a vector network analyzer (VNA) and gather a record of the center rate for internal organ watching. this method was improved for an additional application ,the microwave medical instrument mechanical device, employing a explicit resonator style. However, these strategies need a chic VNA to live the amendment in section, and exhibit terribly low performance sensitivity in vital sign detection.[14]In this work we tend to propose a completely unique RF sensing element system to boost each sensitivity and stability employing a free running voltage-controlled generator (VCO).The PLL periodic circuit of the possible sensing element system is complete by a plate like resonator, that functions as feedback part that is positive, that is close to field radiator to sense very important signals. A surface sound wave filter and power detector square measure accustomed increase the sensitivity of the system also on rework the frequency variation into a voltage undulation. additionally, the relation of the frequency deviation of the generator and also the alphabetic character worth of the resonator was analysed to boost the system sensitivity.[15-17]In this paper, a articulation radio carpea-type wearable sensing element system employing a versatile RF resonator for wrist pulse detection is planned, and was applied as a non-contact and non-intrusive vital sign activity methodology throughout sleep. we tend to any aimed to demonstrate the feasibleness of vital sign activity on the articulation radio carpea victimization numerous RF sensors, like a versatile RF single resonator and PLL resonator sensing element.

II.PULSE SENSOR DESIGN

A.RF system

The RF sensing element system are often divided into 2 parts; the RF resonator and also the detection circuit. The RF resonator half ought to be settled on the articulation radiocarpea near the arteries so as to notice pulses, and also the detection circuit then converts the variation of the reflection constant of the resonator ensuing from pulse motion into terribly low frequency DC-level variations[18]. The sensitivity of the RF resonator and also the detection circuit square measure necessary factors in police work pulses on the articulation radiocarpea. during this Section, many forms of pulse detection strategies supported microwave techniques square measure introduced. A .Flexible RF resonator For wearable applications, like a sensible watch, a articulation plana pulse detection system incorporating AN RF device resonator and detection circuits ought to be tiny and versatile, and have low power consumption similarly. To befits the scale and adaptability necessities, the resonator was designed as a two-dimensional inverted-F antenna (PIFA) structure and enforced on a zero.25millimetre thick Teflon substrate.

The PIFA, similar in form to AN inverted-F, features a low profile, Omni-directional pattern, and comparatively tiny size, as a result of it resonates at quarter-wave length. [19-20]To predict the reflection constant of the resonator, a third-dimensional magnetism full wave problem solver was used. For realistic human skin modelling, the permittivity and physical phenomenon were chosen to be thirty seven and one.7 S/m, severally, at 2.4GHz. In general, the resonant frequency of a resonator is down shifted once a high permittivity material is closely settled. Considering the frequency shifting development, the length of the resonator was set to nineteen.8 mm, that is a smaller amount than ¼wavelength.Also, to extend the frequency deviation of the resonator, that is, the sensitivity of the device, a slit was inserted into the traditional PIFA structure. the scale of the designed resonator was five millimetre x fifteen millimetre. The substrate size, that wasn't relevant to the electrical performance of the device system, was elect to be twenty millimetre x a hundred and sixty millimetre, long enough to wrap round the whole articulation plane. A abstract drawing of the versatile resonator is shown with a hand model in Fig. 1. Because the scale of the resonator is little, a box with a tissue property, like human skin, was placed before of the resonator at a distance ('h' in Fig. 2) starting from zero.25 millimetre to two millimetre, and also the house was stuffed with a preventive layer (εr=3.2). The simulation condition is shown in Fig. 2. The simulation and activity results are illustrated in Fig. 3. The tendency of the activity lead to Fig.3 shows terribly similar behaviour to the simulation result. once there was but one.0 millimetre spacing between the resonator and human skin within the activity, acceptable pressure was applied to match activity result with the resonance frequency changes of the simulation.

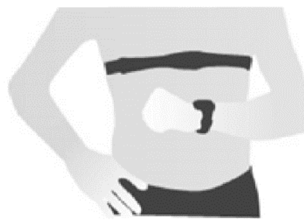


Fig.1.handwristmonitor

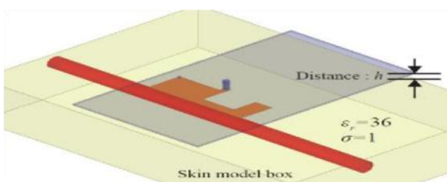


Fig. 2. Simulation condition with the flexible resonator model.

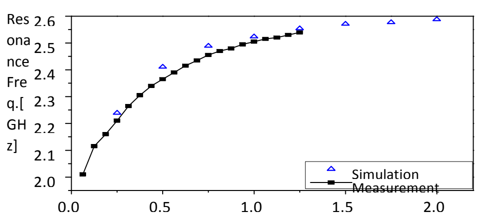


Fig. 3. Simulated and measured S-parameters: 3D EM simulation and measurement results with preventive layers.

B.A Proximity Coupling RF sensor (injection-locked PLL)

The block diagram shown in Fig. 4 is a wrist pulse detection system based on a phase-locked loop (PLL), VCO and sensor oscillator. This system is designed to utilize current communication systems which has VCOs and PLLs and communication antennas. After fleeting the N-counter, the signal from the VCO is compared to value from a reference oscillator which is highly balanced (such as crystal oscillators), by the phase frequency detector (PFD). The PFD produces a DC voltage proportional to the phase difference between those signals, and then the loop filter integrates the signal from the PFD. Note that the type of loop filter used in the paper is a second-order differential active type [21]. Lastly, the DC voltage from the loop filter controls the VCO to adjust the frequency of the VCO to *N* times the frequency of the reference oscillator. Concurrently, the digital signal processing (DSP) is used to digitize the loop control voltage for ADC post-processing [22].When an external signal having a frequency similar to the VCO is injected, such as the wrist pulses, the VCO tends to be locked by this external signal. Then the PLL generates a control voltage to the VCO to return to the original frequency of the VCO. So the VCO frequency is fixed but the control voltage is continuously varying with the external signal. Note that the sensor oscillator behaves like the external signal in this system. The sensor oscillator in this work consists of an inter-digital planar resonator and a buffer amplifier. This terminology comes from its structure (i.e., finger-like, periodic, and parallel pattern), and this type of resonator has been used to sense variations in the dielectric constant of MUT (material-under-test) non-destructively [23]. When this resonator approaches the wrist where the radial artery passes, the fringing field of the resonator is affected by the periodic variation of the radial artery; hence, the oscillating condition of the sensor oscillator is changed. This sensor system has several advantages: 1) the proposed system can be easily combined into actual communication systems, such as Bluetooth, Wi-Fi, or 4G mobile communication systems, by adding an injection port to the PLL circuit, whereas other demodulation methods are designed to be independent of existing communication systems for the purpose of tracking vital signs. 2) The sensor system does not interfere with other external communication systems, in contrast to transmit/receive signal-based systems, such as Doppler radar. 3) It has high degrees of freedom since there are various design parameters which a designer can control, such as VCO gain, VCO power, injection power from the sensor oscillator, and the Q of the resonator.

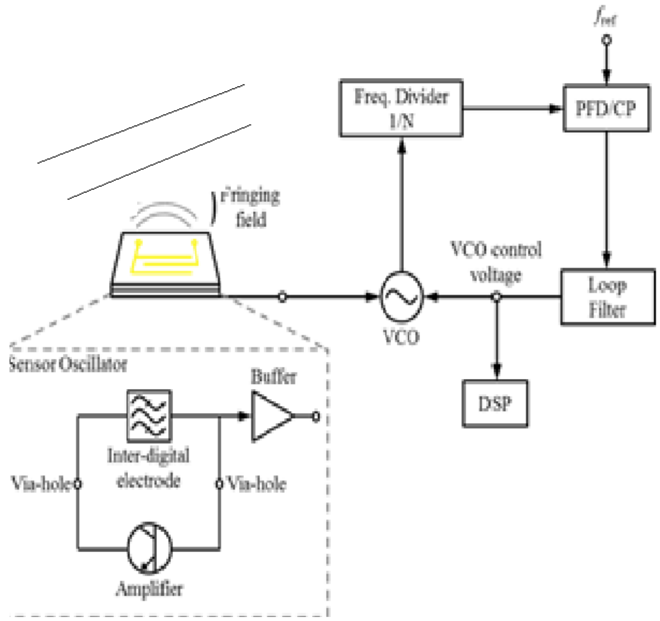
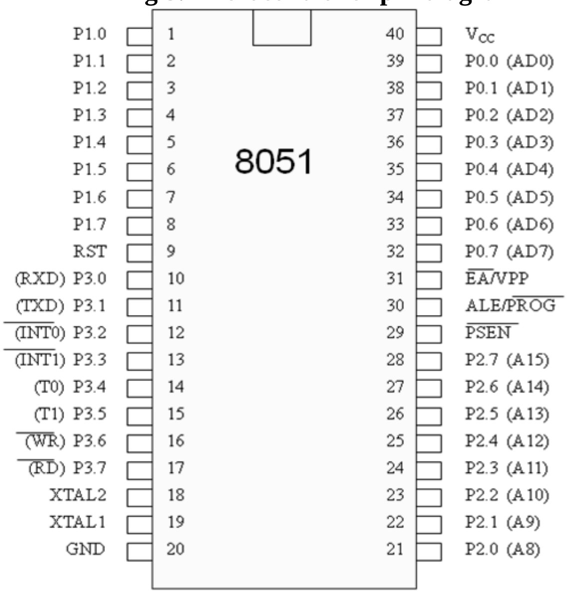


Fig. 4. Block diagram of PLL Sensor

C. Micro Controller and Multisim

Micro controller is a single integrated circuit which contains memory, program input and output, core processor small computer. Microcontroller are used in embedded systems. They are used in many applications like computers, traffic lights, robots. Multisim is simulation software tool which is part of suite of National Instruments. Multisim includes microcontroller simulation and integrated imports and exports features to printed circuit boards layouts in software.

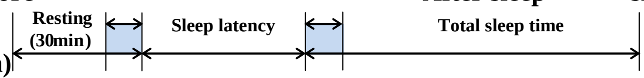
Fig 5. Microcontroller pin diagram



III.MEASUREMENT AND SIMULATION RESULTS

As shown in Figure, which describes our experiment, the heart rates of 10 healthy are measured before sleep and after sleep onset time. To prepare for the measurements, the subjects wore a convenient EEG headband which provided a reference for sleep stage, and the flexible RF single resonator, before lying down on the bed. For comparison with the wrist pulse signal obtained from the flexible RF single resonator, we used a portable piezo-electric transducer.

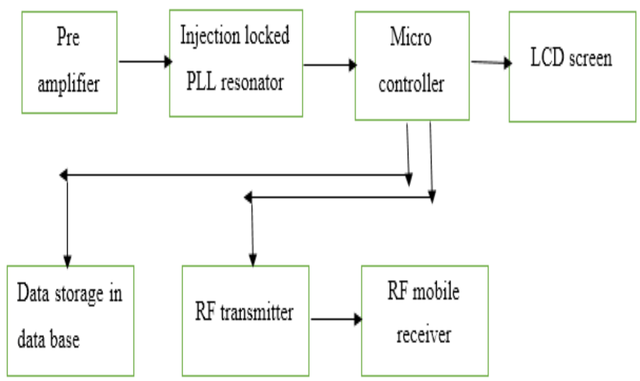
Before **After sleep** **sleep** **(5 min)** **(5**



min) **Sleep** **Wake** **onset time**

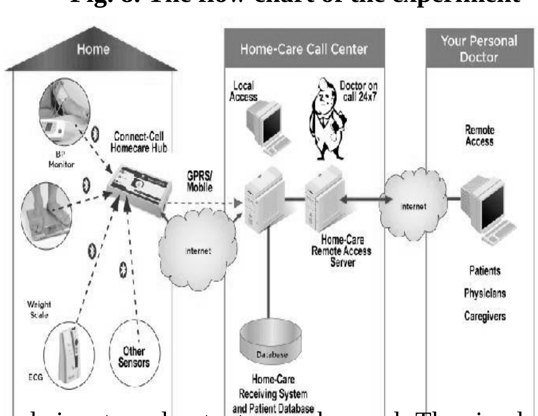
Fig. 6. The flow chart of the experimental protocol. The shaded area indicates that wrist pulses were measured by the flexible RF single resonator for each 5 min segment. The changes of resonant frequency, magnitude, and phase of the reflected microwave, used for wrist pulse detection, were detected by our sensor. Here the output of PLL sensor is given to amplifier to increase the signal level. The signal is then given to ADC (Analog to Digital Convertor) to get digital values. The digital signal is given to microcontroller. The microcontroller judges whether the signal is to be given to mobile for changes in heart rate. The message is sent through RF transmitter receiver circuit.

Fig.7. Detailed Block diagram of the experiment.



After 30 min resting period, the test subject's heart rate was recorded for 5 min using PLL sensor and microcontroller with GPRS we can transmit and monitor the data and health condition of heart. The data is stored in computer as shown in figure.8

Fig. 8. The flow chart of the experiment



The flexible PLL resonator signals inputs and outputs are observed. The simulations are taken from Multisim until detection part before giving to microcontroller. The simulation waveforms obtained are shown here in the multisim.

Fig.9.(a).Pre-amplified-signal

Fig.9. (b).Output of PLL resonator signal conditioning unit

The Fig.9.(a) gives the pre amplification signal of pulse of wrist which is seen as input to PLL sensor. The next fig.9.(b) gives the final output after comparison and gives the pulse output. The variations show the actual signal obtained is corrected in PLL.

IV.DISCUSSION

This is to first study in detecting heart rates which are very close distance from the skin of the wrist during sleep using an RF system. Heart rate monitoring in polysomnography has previously been conducted by measuring ECG, which is quite intrusive and constrained due to the electrodes and lead wires attached to patients. In contrast, the RF system can measure wrist pulse through clothes made of cotton fabric. This non-contact and non-intrusive measurement of wrist pulse makes comfortable long term. We were able to measure heart rates on the wrist during sleep and waking states using the flexible RF sensor system. We confirmed that the heart rate significantly decreased during sleep. Our results on the differences of heart rate during sleep are similar to results in related previous studies [24].The next step is to send the information to microcontroller to display the data in LCD. The data is also stored in data base server. When the results are abnormal thena message is sent to person about heart beats changes. The request message is sent to hospital or to consult a doctor for treatment. This gives a safety to the patients from heart attacks.

V.CONCLUSION

In this study, it was demonstrated that an RF system could measure heart beat signals using a non-contact non-intrusive method, and that the heart rate during sleep significantly decreased. Moreover, we newly proposed types of RF sensor for heart rate measurement on wrist like injection-locked PLL resonator sensor using microcontroller.[25] Therefore, our RF system could be a useful method for measuring heart rate during long-term monitoring, because it has the advantage of being a less intrusive measurement method, using a non-contact approach rather than traditional electrodes and PPG sensors. Also the message sent helps in saving person life.Our future study will be to measure heart rates in far field during sleep.

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