The Use of Inexpensive Cell Phones in Telemedicine

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Abstract

The modern world has seen an increase of life expectancy through the progress made in the fields of hygiene and health. The increase in the life expectancy of the society and the presence of the senile will cause problems related to old age. The present article tries to provide a new strategy for transmitting patient's vital data to the monitoring station. The new strategy is characterized with low costs and simplicity of use. The patient's vital signals will be modulated in independent frequencies, merged and then placed on a cell phone voice channel. The allocated frequency channels have a bandwidth of 1.5 KHz and thus provide a theoretically good margin of safety for meeting the condition of lack of frequency overlapping. Finally, the signals will be demodulated and displayed using AM demodulators in the receiver.

Key words: Telemedicine, Cell Phone, ECG, PPG.

1. Introduction

The increasing progress of health related technologies in recent years has brought with it a variety of methods for designing medical and telemonitoring systems. There are two categories for telemonitoring systems: 1.continuous monitoring and 2.Periodic observation of data. In both systems, medical data are transmitted to monitoring systems through telecommunication. For example, the physician can study the vital signals of the patient through internet [1] [2] [3] [4].

There have been a plethora of studies on increasing the efficiency of these systems through different methods [2] [3] [5]. The problems of the proposed methods include high cost of the system and the complexity of the instruments. Therefore, the present activity tries to provide a new method which is both cost-effective and easy to use. The inexpensiveness of some cell phones (Nokia 1202 for $14 compared to different types of PDAs) caught our attention and

we decided to use them in our telemedicine system. One way to transmit data on these cell phones is to use their sound channel which has a bandwidth of 13.2^{KHz}.
For the purpose of evaluating the performance of the system, we used the two vital signals ECG and PPG. The system allocates a separate frequency to each signal and transmits the data to the receiver based on Frequency Division Multiple Access (FDMA) and linear domain modulation (AM). Then, the receiver demodulates the received signal and receives the vital signs in analog signals. This system does not require a controller section or analog to digital converters because this method is based on analog modulations. The system is also cost-effective in terms of design costs.
The rest of the article is organized as follows. Section 2 introduces the monitoring network structure. Section 3 present a description of the simulation and section 4 concludes the article.

2.Monitoring network structure

2.1. Transmitters

Based on the situation and the disease, optimized vital signals can be chosen in any telemonitoring method. One of the extensive fields dealing with a broad audience is telegeriatric. According to [1, 2-4, 8], in the field of telegeriatric signals such as SpO2, HRV, PPG, ECG, temperature, acceleration and EMG can be suitable vital signals for the system. We chose ECG and PPG signals for establishing a system that can be used in evaluating the performance of this method.

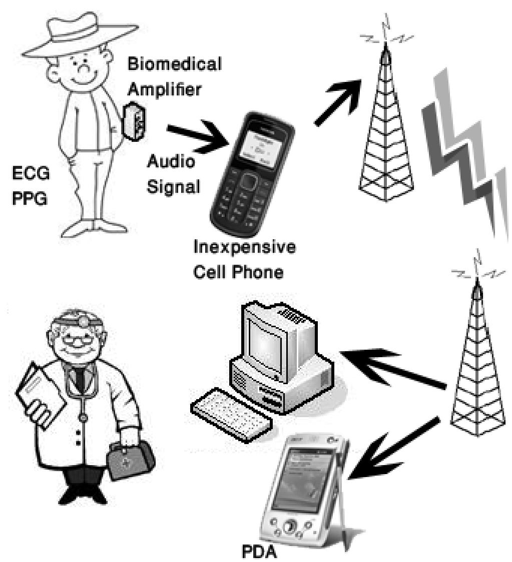

Fig 1: System Architecture

ECG and PPG signals have frequency domains of DC-150 and DC-30 respectively. Obviously, transmitting data using the TDMA method will be problematic. In the FDMA method, we chose two carrier signals for transmitting data with AM modulation in 4^{KHZ} and 8^{KHZ}. A frequency difference of 4^{KHZ} provides a good margin of avoiding frequency overlapping in the transmission band. Fig 2 illustrates frequency allocation.

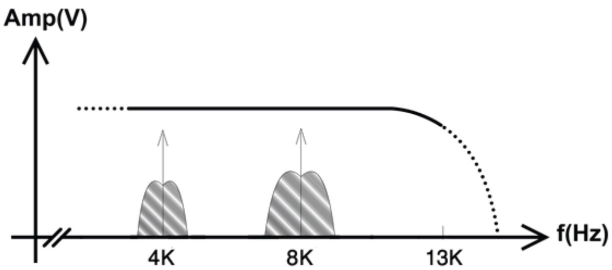

Fig 2: Frequency allocation

As shown in Fig 2, ECG and PPG information signals are modulated with the suitable carrier signals, the modulated signals are added in an adder and since the obtained signal is in the sound frequency range, it can be placed on the cell phone sound channel as input signal.

Eq.1 explains the relationships governing the system:

$$|ppg(t)| < 1; \quad |ecg(t)| < 1;$$
$$AM(t) = [A_1 \cos(\omega_1 t) * (1 + \mu_1 ppg(t))] + [A_2 \cos(\omega_2 t) * (1 + \mu_2 ppg(t))] \quad \text{(Eq. 1)}$$

In the above equation, ECG and PPG signals are modulated with Cos(ω_1) and Cos(ω_2) respectively. Cos(ω_1) and Cos(ω_2) are carrier signals with A_1 and A_2 domains and μ_1 and μ_2 are modulation indexes. In figure 3, NL is an attenuator with gain μ. It also has a cutter for noise removal[4].

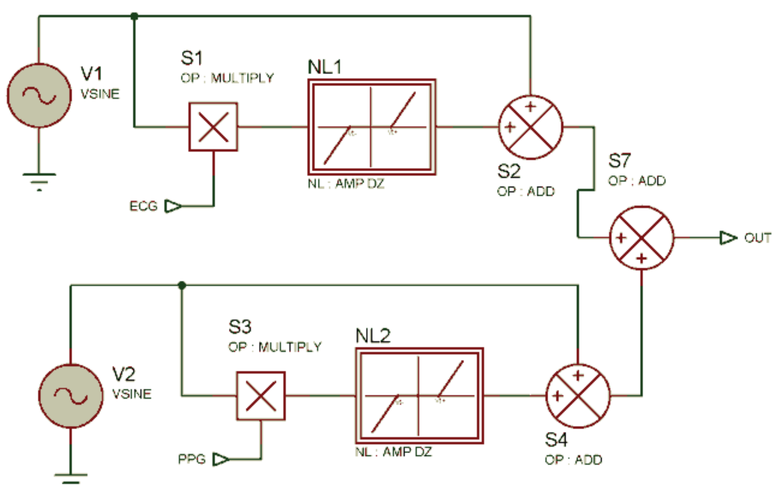

Fig 3: The structure of amplitude modulators

2.2. Receiver

Since this method is based on transmission of analog data, analog modulation is considered suitable for our purpose. Therefore, we need an analog demodulator toward the receiver. Since our main goal in this article is to lower the costs of telemedicine systems, we use digital demodulators instead of analog demodulation with electronic circuits.

After arriving at the receiver, the transmitted signal passes through an active 4th order low-pass IIR with cutoff frequency of 13.2^{KHZ}. In this phase, RLC filters are used for separating ECG and PPG. Table 1 presents the characteristics of these filters.

Signals	BW	Q	F_0
ECG	1 KHz	8	8 KHz

PPG	200 Hz	20	4 KHz

Table 1. Characteristics of filters

The signals separated for demodulation pass through common AM detectors and extract the transmitted PPG and ECG signals. Since the signals were attenuated in the channel, they need to be amplified using an amplifier. Eq. 2 explains the relationships governing the received signals:

$$ecg'(t) = K_1 \alpha_1 ecg(t) Cos(\varphi_1)$$
$$ppg'(t) = K_2 \alpha_2 ppg(t) Cos(\varphi_2) \quad \text{(Eq. 2)}$$

In the above equation, K_1 and K_2 are reinforcement factors, a_1 and a_2 are attenuation factors of the channel and φ_1 and φ_2 give us the phase variation between the carrier and the local oscillator in case of using a synchronous demodulator (for envelope detectors, φ_1 and φ_2 will not exist).

Now, a 10 bit analog to digital converter, converts the signal with a sampling rate of 1^{KHz}. The resulting digital signal is red by an AVR microcontroller and then turned into serial data at a rate of 128KB/S. Finally, a serial to USB converter, transfers data to a computer USB port.

Software management of the data was done through designing software using Visual Studio .net 2008 and C#. Thus, the nursing team will be able to carry out monitoring and the patient's vital signs data can be transmitted at the lowest cost and with the least complexity.

3. Results and Analysis

Computer simulation was used in order to evaluate the performance of the proposed system. The software used for simulation is Proteus 7.4 sp3.

An ECG period and a PPG period were recorded from a healthy person in one heart cycle with a sampling rate of 400^{Hz}. This record can be used as input to each of the modulators.

In this simulation, ω_1 and ω_2 were chosen 4^{KHz} and 8^{KHz} respectively, μ_1 and μ_2 both 0.1 and A_1 and A_2 both 10. The applied noise is a Gaussian noise with a variance of 0.1 and a mean of zero.

Based on the mentioned values, the output of the simulated system for the ECG signal is presented in Fig 4.

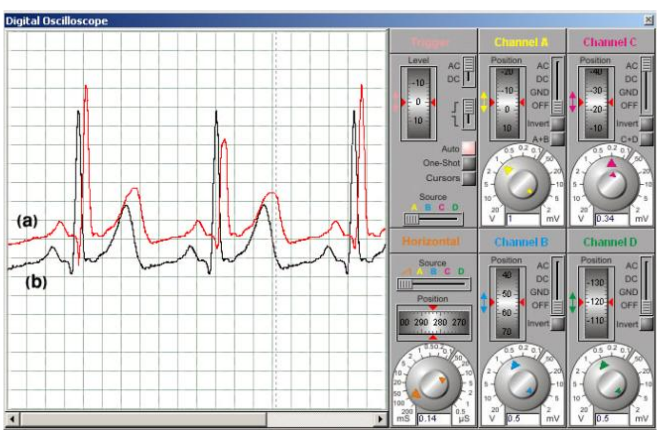

Fig 4: signal (b), simulator output; signal (a), system output

4. Discussions and Conclusions

In this paper, we used a simple and inexpensive method for transmitting patient's vital signs in telecommunication. The proposed system transmits modulated ECG and PPG information in the form of AM modulation on the GSM network sound channel.
Although transmission of data through a sound channel has disadvantages such as complexity of calibration, signals in which domain is unimportant (such as the two chosen signals) can be a good choice for the proposed system.

5. Recommendations

Since this system is one of the newest methods in telemonitoring, there are many ways to improve the system. For example, automatic calibration can be achieved through sending a cosine signal with fixed accurate domain and frequency and then receiving it at the receiver.
Another recommendation is presenting a method for merging and compressing signals. This method can help us make the best use of the accessible bandwidth and send signals to higher bandwidths.

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