ECG Acquisition and Simulated Transmission by Various Modulation Techniques with Analysis

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ABSTRACT
Wireless Networks have been dominating in the present world in almost all the domains and departments especially in the medical field. This work gives the scenario of implementation of wireless transmission of biomedical signal, ECG (Electrocardiogram) in particular using the methods of Angle Modulation viz., Frequency Modulation and Phase Modulation. The ECG signal is acquired using the ECG Amplifier circuit and then it is transmitted using the Angle Modulation. However the transmission is Simulated rather than the hardware transmission which gives the idea of implementing in the real world application. The validation of faithful transmission is done using the parameter of ECG waveform i.e., amplitude and frequency. Also for patients in rural, regional and remote areas an ECG report could be sent via email or LAN to a doctor for examination. An added advantage is economically feasibility which is the main concern in the medical field [1].

General Terms
Biomedical Signal Processing, Analog Communications.

Keywords
Angle Modulation, Bradycardia, ECG,Frequency Modulation,Phase Modulation, Simulation, Tachycardia.

1. INTRODUCTION
The electrocardiogram (ECG also called as EKG) is a non-invasive type of measurementto analyze the electrical activity of the heart. An ECG can be used to measure the rate and regularity of heartbeats, the working of the chambers, the presence of any damage to the heart and the effects of drugs and devices used to regulate the heart. This procedure is very useful for monitoring people with heart disease or to provide diagnosis when the patient has chest pains or palpitations.

Leads are placed on the body in several pre-determined locations, usually the extremities viz., Limbs or the front of the chest, to provide information about heart conditions. The measurement may be either continuous or timely.

Modulation is the process of varying one or more properties of a high-frequency periodic waveform, called the carrier signal, with respect to a modulating signal (which typically contains information to be transmitted). There are two types of Modulation Techniques viz., Analog & Digital Modulation Techniques [1].

The aim of analog modulation is to transfer an analog baseband (or lowpass) signal, for example an audio signal or TV signal, over an analog bandpass channel, for example a limited radio frequency band or a cable TV network channel. Whereas The aim of digital modulation is to transfer a digital bit stream over an analog bandpass channel, for example over the public switched telephone network (where abandpass filter limits the frequency range to between 300 and 3400 Hz), or over a limited radio frequency band.

This paper gives the Technique of Analog Modulation using Angle Modulation in which the frequency or phase of carrier is varied in proportion to the amplitude of the modulating signal. If frequency is varied it is called as Frequency Modulation & if Phase is varied itis called as Phase Modulation.

2. LITERATURE REVIEW
According to Beery (1998), nurses outside of critical care are being asked to take care of patients with cardiac dysrhythmias. Nurses have significant diagnostic influence in the areas of cardiac rhythm monitoring and dysrhythmia identification (Hebra, 1994). It is essential that nurses who care patients at risk for cardiac dysrhythmias have a thorough understanding of accurate electrode placement.

EKG monitoring is becoming more common in both inpatient and outpatient care settings (Scrima, 1997).Critical care nurses also need to maintain and enhance EKG skills. Keller Buchanan, K. and Raines, D. (2005) published a qualitative study of critical care nurses which indicated that the skills necessary to recognize and treat arrhythmias could be catagorized as basic, intermediate or advanced. Identification of specific arrhythmias including heart block, aberrant conduction, and tachyarrhythmias varied across training and experience levels within the test sample [2][3].

3. PROCEDURE

3.1 ECG Acquisition
The electrical impulses within the heart act as a source of voltage which generates the ECG signal. If two leads are connected between two points on the body (forming a vector between them), electrical voltage observed between the two points is given by the dot product of the two vectors. These voltages are observed by Electrodes which make a transfer from the ionic conduction in the tissue to electronic conduction when necessary for making measurements [4]. An accurate indication of the frontal projection of the cardiac vector can be provided by three leads/electrodes, one connected at each of the three vertices of the Einthoven triangle as shown in figure1.

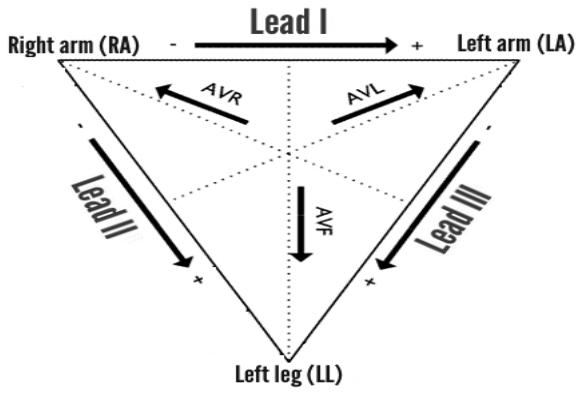

Fig. 1 Einthoven Triangle

3.2 Block Diagram

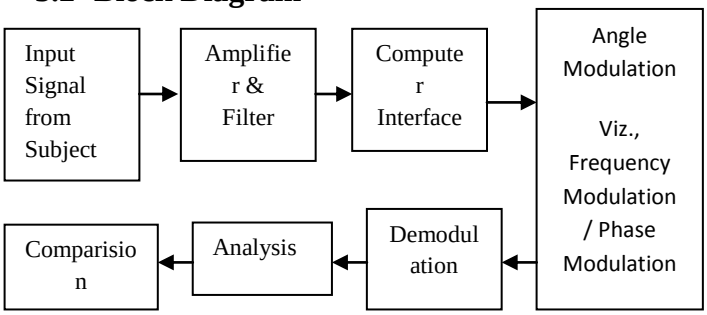

Fig 2. Block diagram of the Module

The Input signal using the bipolar leads electrodes is acquired and fed to ECG Amplifier. The chances of having low frequency noise are high. Therefore a Low pass filter is used to eliminate the noise and then interfaced to the computer at the Audio port. Using a suitable software the signal coming to the audio port is plotted and stored [5]. A software filter can be applied to the acquired signal if required [6]. Then we use the concept of Simulated Angle modulation by both Frequency & Phase Modulation. Here the message signal is the acquired ECG signal. Then demodulate and calculate the efficiency of both the Modulation process. These processes are compared and finally a conclusion is drawn based on the efficiency and Signal to Noise ratio.

3.3 Angle Modulation

Consider a sinusoid, $Cos(2\pi f_c t + \varphi_0)$, whereAc is the constant amplitude, f_c is the frequency in Hz and φ_0 is the initial phase angle. Let the sinusoid be written as $Ac\ Cos[\theta(t)]$where $\theta(t) = 2\pi f_c t + \varphi_0$. Let$Ac$ be a constant and making it a function of the message signal $m(t)$, gives rise to amplitude modulation. $\theta(t)$is a function of $m(t)$. This leads to what is known as the angle modulated signal [7]. Two important cases of angle modulation are Frequency Modulation (FM) and Phase modulation (PM). Our objective in this paper is to use FM and PM for transmitting the ECG signal after acquisition [8] [9].

a) Phase modulation

For PM, $\theta_i(t)$is given by

$$\theta_i(t) = 2\pi f_c t + k_p m(t) \quad \text{--------} (1)$$

The term $2\pi f_c t$ is the angle of the unmodulated carrier and the constant k_p is the phase sensitivity of the modulator with the units, radians per volt.

Using Eq. 1, the phase modulated wave $S(t)$ can be written as

$$[S(t)]_{PM} = A_c\ Cos(2\pi f_c t + k_p m(t)) \quad \text{--------} (2)$$

From Eq. 1 and 2, it is evident that for PM, the phase deviation of $S(t)$from that of the unmodulated carrier phase is a linear function of the base-band message signal, $m(t)$. The instantaneous frequency of a phase modulated signal depends on$\frac{dm(t)}{dt} = m'(t)$.

b)Frequency Modulation

Let us now consider the case where $f_i(t)$ is function of $m(t)$; that is,

$$f_i(t) = f_c + k_f m(t) \text{or} \theta_i(t) = 2\pi k_f \int_{-\infty}^{t} f_i(t) \int \tau\ d(\tau)$$

$k_f$is a constant. A frequency modulated signal $S(t)$ is described in the time domain by

$$[S(t)]_{FM} = A_c\ Cos(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} f_i(t) \int \tau\ d(\tau))$$

$k_f$is termed as the frequency sensitivity of the modulator with the units Hz/volt.

3.4 Simulation

Simulation is the imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviours of a selected physical or abstract system. Simulation is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, trainingand education. Medical simulators are increasingly being developed and deployed to teach therapeutic and diagnostic procedures as well as medical concepts and decision making to personnel in the

health professions. Simulators have been developed for training procedures ranging from the basics such as blood draw, to laparoscopic surgery and trauma care. They are also important to help on prototyping new devices for biomedical engineering problems. Currently, simulators are applied to research and development of tools for new therapies treatments and early diagnosis in medicine.
In this work, a software simulation is implemented for the transmission of the ECG signal through both the types of Angle Modulations. The advantage of Simulation is that there is no need of any investments as well as accuracy is very important and non-compromising especially in the field of Medicine. Therefore it is better to go for simulation at the pilot phase and then for actual implementation.

4. ANALYSIS

The Analysis of the acquired ECG signal consists of calculating the Heart Rate from the Demodulated ECG and then commenting on the cases of abnormality. These abnormalities / Deviation from the normal value are called as Arrhythmias [10].

An arrhythmia is a disorder of the heart rate (pulse) or heart rhythm. If heart is too fast, then it is termed as tachycardia and too slow as bradycardia. The normal typical value of heart rate is 72bpm (Beats per minute). Therefore a threshold was set for Minimum and Maximum values of normal heartrate. Anything in between 60bpm to 100bpm is considered as normal else the deviation as abnormal. Table 1 gives the analysis weather a given signal is Normal and Abnormal [11].

The electrical impulse that signals the heart to contract begins in the sinoatrial node (also called the sinus node or SA node). This is also known as heart's natural pacemaker.

- The signal leaves the SA node and travels through the two upper chambers (atria).
- Then the signal passes through another node (the AV node). Finally, it passes through the lower chambers (ventricles).
- Different nerve messages signal your heart to beat slower or faster.

Therefore, any abnormality in the above conduction it is called as Arrhythmia [12].

5. COMPARISON OF FM AND PM

The Angle modulation types i.e., both FM and PM are performed on the acquired ECG signal and then Demodulation is done in order to recover the ECG signal. It was found using trial and error method that for faithful and without attenuation to reproduce the signal the frequency deviation constant, K_f should be 3 in FM and Phase deviation constant, K_p should be 0.001 in PM [13]. Using these values the efficiency is calculated. The method of Efficiency calculation was done by taking the ratio of Demodulated signal to the Message signal. It was found that the efficiency was better in Phase modulation than in Frequency modulation [14][15].

6. RESULTS

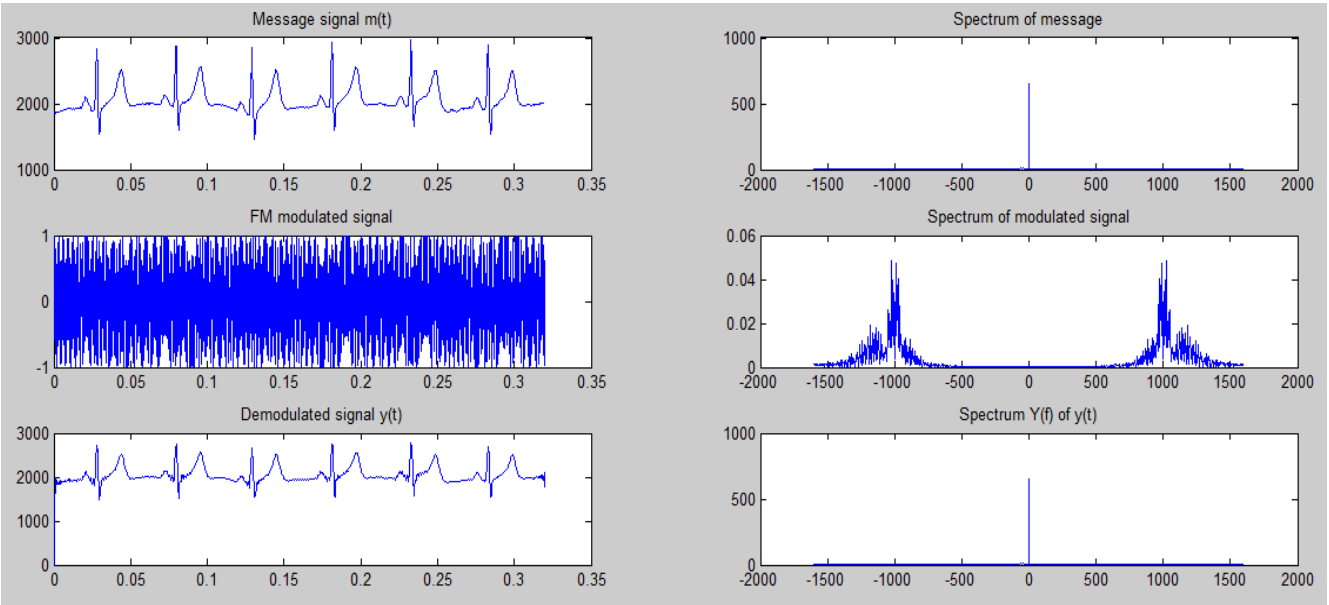

Fig. 3 Top row: ECG Signal transmitted signal and its Spectrum.
Middle row: FM signal and Its Spectrum.
Bottom row: Demodulated Signal and its Spectrum

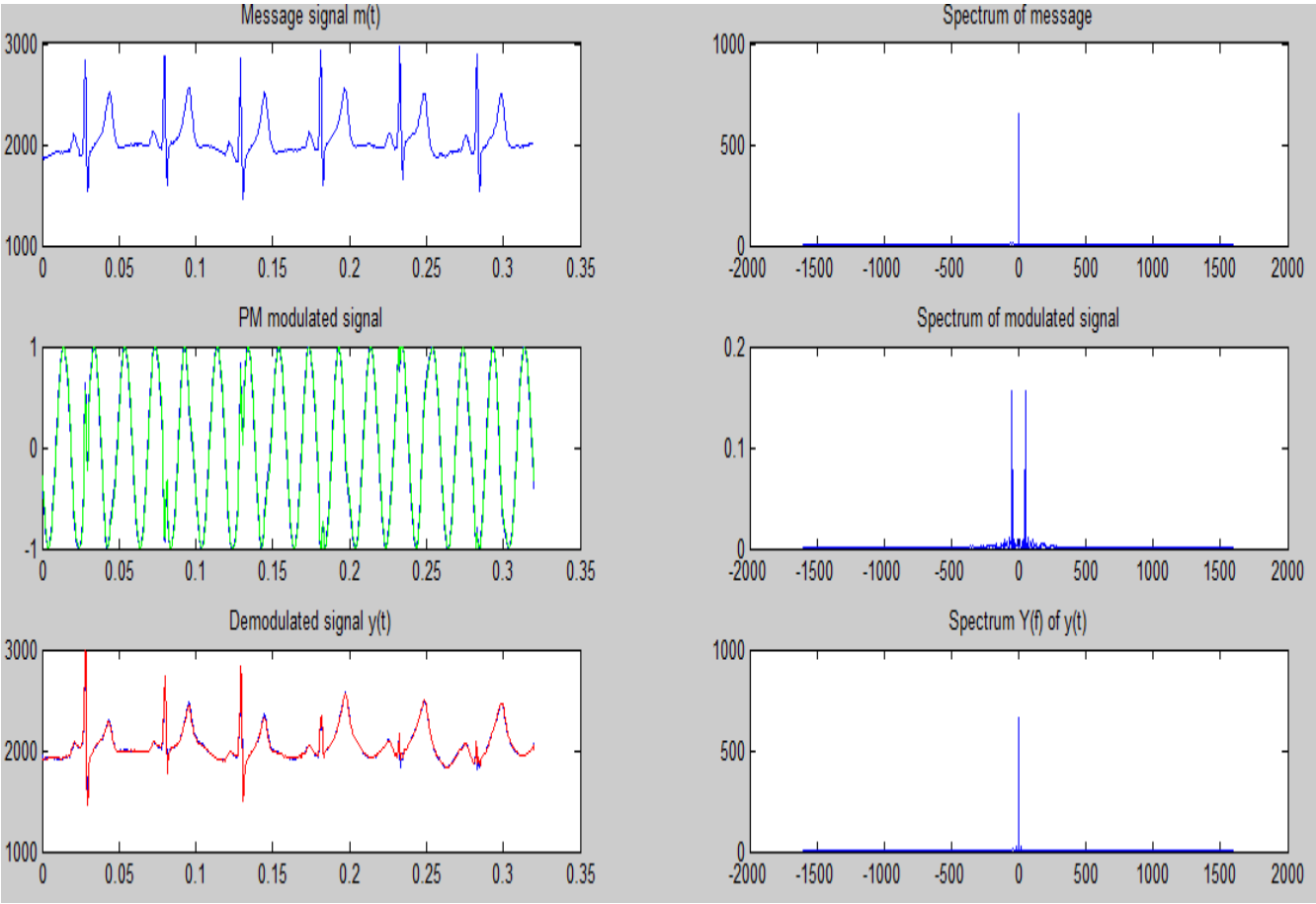

Fig. 4 Top row: ECG Signal transmitted signal and Its Spectrum.
Middle row: PM signal and Its Spectrum.
Bottom row: Demodulated Signal and its Spectrum

The ECG signal was acquired and Modulated for 33 Subjects and the tabular column show in Table 1 the analysis of the demodulated ECG.

The work is never complete unless a proper standard acceptable validation is done. The validation is done for all the subjects and it was found that the wireless device was showing almost same values as the conventional machine. The table 1 shows the values of 10 Subjects and their comments on the Arrhythmia w.r.t heartbeat [16].

Table 1: Comparison of Conventional ECG w.r.t Wireless ECG for Validation with Analysis

Subject	Wireless ECG (bpm)	Conventional ECG (bpm)	Comments
1	75	75	Normal
2	102	102	Tachycardia
3	66	68	Normal
4	70	70	Normal
5	59	60	Bradycardia
6	69	69	Normal
7	70	72	Normal
8	99	97	Normal
9	58	61	Bradycardia
10	91	91	Normal

7. CONCLUSION

This paper gives the idea of implementation of Wireless technique in simulated environment & this device is an indigenous and less expensive device comparing to the existing device without compromising on accuracy.

Compared to Frequency modulation, phase modulation has better accuracy. This work has been implemented assuming Ideal conditions, but practically there will be lot of interference of noise and other environmental factors affecting the message signal for transmission. Therefore, FM suppresses noise better than PM. However the application of FM is mostly for Entertainment purpose and PM is for mobile communication and for accuracy purpose.

8. FUTURE DEVELOPMENT

The work can be extended for practical implementation in hardware wireless transmission and making the circuit more immune to noise [17][18]. The analysis part can be extended in detection of any abnormality other than arrhythmias like extracting QRS complex and commenting on elevation of ST interval. With the above developments the calculation of each intervals and Amplitudes can be found out using automated algorithms. Other Modulation techniques like DPCM, etc can used for transmission [19].

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