Design and Implementation of Fast Ambulatory System for Cardiac Patients Using GSM Network and ECG Signal

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Abstract
This paper presents, the design and implementation of fast ambulatory system for cardiac patients by using global system mobile (GSM) network and Electrocardiography (ECG) signal. The early detecting of critical case in the heart performance gave enough time to help the patient with heart disease. Depending on the filter response and ECG band limited signal, the proposed system generate voice alarms to the monitor when the time band of the QRS complex wave in the ECG signal is exceeded the standards durationwhich indicate that the patients in dangerous condition and arrhythmia may be founded. The FIR filter response analyzed the distorted ECG signal and produce an alarm which will be send by GSM transmitter to the nurse or doctor mobile phone reciever at monitor center when the ECG frequency band jumb over natural frequency and high risk of cardiac patients. The low pass FIR filter performance using kaiser window permit to pass only the natural band otherwise send emergency alarms via GSM mobile phone. Results shows and efficient and hilight observation with each case recording by FDAtool in MATLAB.

Keywords- Fast Ambulatory, Cardiac Patients, ECG, GSM, MATLAB

تصميم وتنفيذ نظام الاسعاف الفوري لمرضى القلب باستخدام شبكة النظام العالمي للهاتف المحمول (جي إس أم) وإشارة جهاز تخطيط القلب الكهربائي (أي, سي,جي).

الملخص:
تعرض هذه الورقة، تصميم نظام فعال في حالات الطوارئ للمرضى الذين يعانون من أمراض القلب، استناداً إلى إشارات تخطيط القلب الكهربائية (ECG) باستخدام مرشح عامل تصفية الاستجابة (FIR) وشبكة النظام العالمي للهاتف المحمول (GSM). أنالكشف المبكر للحالة الحرجة في أداء القلب تساعد على تقديم المساعدة للمريض بمرض القلب في وقت مبكر اعتماداً على استجابة المرشح وإشارة الحزمةالمحدودة لتخطيط القلب الكهربائي ، أن النظام المقترح يولد الإنذارات الصوتية إلى جهاز العرض عندما تتجاوز وقت الموجة المركبة في إشارة تخطيط القلب الكهربائي لاكثر من0.08من الثانية مما يشير إلى أن المريض في حالة خطيرة وعدم انتظام ضربات القلب. أن تحليل إشارة تخطيط القلب الكهربائي المضطربة باستخدام مرشح عامل تصفية الاستجابة (FIR)يولد إنذار الذي سيرسل عبر شبكة النظام العالمي للهاتف المحمول(GSM) الى متلقي الهاتف المحمول كالممرضة أو الطبيب عندما تتجاوز ترددات القلب عن التردد الطبيعي في تخطيط القلب الكهربائي وحدوث خطورة عالية لمريض القلب. باستخدام مرشح عامل تصفية الاستجابة (FIR) منخفض التمرير باستخدام نافذة كايزر تسمح لتمرير الحزم الطبيعية فقط وإلا سيتم إرسال إنذارات الطوارئ تحت تكنولوجيا البرمجيات الراديو عن طريق الشبكة الدولية للهاتف النقال GSM. النتائج تظهر كفاءة، وتسلط الضوء على المراقبة مع كل حالة تسجل عن طريق أداة تصميم الفلتر الرقمي (FDA tool) في MATLAB.

Introduction

The Electrocardiography machine records signals from the patients body and it is useful in identifying patients with coronary artery disease and dangerous arrhythmias or a portion of the heart has been damaged, the affected muscle cells will no longer conduct action potentials, so an ECG will reveal an abnormal pattren of impulse conduction[1,2]. In one-fourth of patients with coronary disease the sudden death may be the first clinical manifestation. In addition, 20% of patients with myocardial infarction will die before reaching a hospital. Most of these deaths are caused by ventricular fibrillation[3]. When ST segment depression of ECG exceeds 0.1 mV, is strongly suggestive for ischemia. The ECG changes in myocardial infarction with classic evolution is from peaked (hyperacute) T wave, to ST segment elevation, to Q wave development to T inversion. The evolution of new Q wave (> 30 ms in dutration and 25% of the R wave amplitude) is diagnostic[4].

In recent years, the modern communication system is used in health care for many performing such as surgery and delivering assistance to the patients in the form of telemedicine and biotelemetry using local area network (LAN) and radio frequency(5). To establish these technology required more investment with slow return rate(6). The medical facilities not provide full extent in all over the word due to poor transportation with large distance. However, the current communication technology should be applied in home automation and networking. By using the GSM network, the heart patients data could be moved emmediatly to the doctor in charge and surveillancenurse(7). The trasmitter and reciever in GSM mobile system can be used to transmitte and receive the patients information instantly for early detectionof any emergency case after some signal processing like digital signal processing (DSP). The FIR filter is one of the signal processing part which used to pass an accurate band of interest and neglect the undesired band (8). The patient monitoring system is placed near patient bed and connected to the mobile phone by mean of wireless technology or interfacing with personal computer for more processing associated the physician room(9). The GSM network interfacing and analysis the

ECG signal by FIR filtration with kaiser windowing techniques (10). The attractive characteristics in frequency domain of kaiser window will produce high efficiency and capability in the noise elimination than other windowing techniques (11). The ECG filtration by FIR filter performs earlier analysis to minimize the false detection rate and decrease the time spent by this processing (12). Consequently, the software defined radio (SDR) technology used in the FIR filter design minimize and optimize the power consumption to lowest level as well (13). The need of having modern tools like SDR technology and portable devices allow the biomedical signal recording to further study of the high prevalenceof cardiovascular diseases (14). The use of SDR technology help the medical staff to capture process and store signals from the patients to perform succeeding analysis and comprehensive clinical studies in order to make more perfect decisions (15). The alarm message sending therought mobile communication device via mobile phone could be reduce the emergency time to assist patients and staff in the telemedicine services (16). The selection of appropriate technology to develop a suitable design in the software and hardware side and perform good analysis detection assist the patients to move from critical situation to stable case early (17). The development of bioengineering applications becomes more popular technology and wide used due to fast and accurate results of patients assistance (18). In this paper, the combination of digital signal processing (DSP) technology with ECG monitering device depend on the ECG duration is developed and investigated using FIR filter and SDR technology. Figure 1 shows the conventional designs of ECG transformation via GSM system depending on the heart beat per minuts (BPM) proposed by (19).

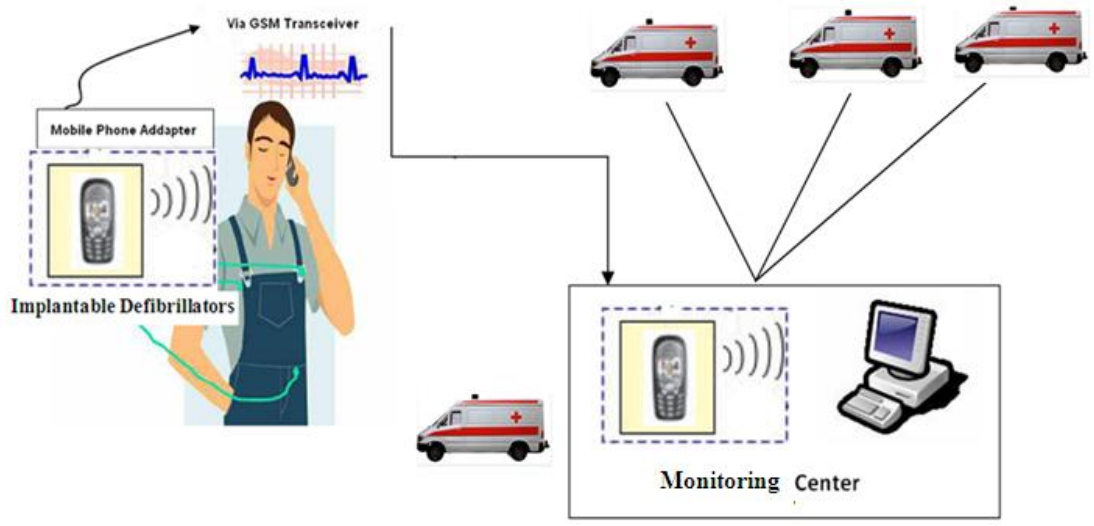


Figure 1: Proposed ECG trasfer system

The design method accessible can be basically comprehensive to FIR highpass (HP), bandpass (BP) and bandstop (BS) filters. Consider the case of BP filter is requied that would satisfy the specifications of heart signal band. The only differences in the design of BP filter are to use the more critical of the two trasition width for the design and the idealized frequency of BP filter for the determination of the initial impulse response.

I. Proposed System

The proposed system shown in Figure 2 represent the GSM transciever that performs ECG analysis and transformation by using the digital modem with FIR Kaise window technique. Decision whether the person is normal or abnormal is based on calculating the value of ECG interval and if any abnormality is detected, the system initiates an command to the inbuilt GSM Baseband Processor module, which sends an SMS to physician or caretaker mobile through the SIM module. Analysis of the ECG signal is done by performing the FIR decomposition followed by upsampling filter to increase the modulated frequency from baseband to intermediate frequency (IF). The FIR filter permit to pass only 0.12 secondband in an ECG signal. The stadards amplitude range of ECG signal is 1-10mV and its frequency range is 0.05 -100 Hz. Simulation performed in MATLAB environment using the FDATool.

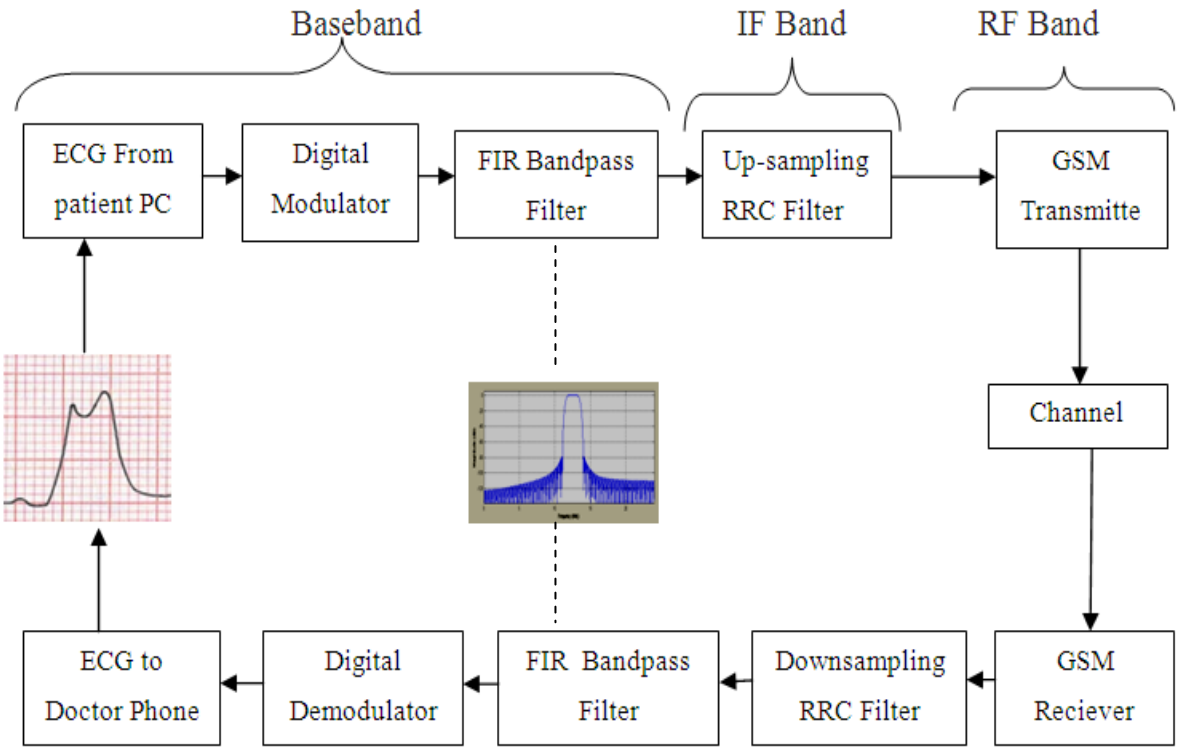


Figure 2: Proposed design for ECG transportation using GSM system and MATLAB

A. GSM Transciever Design

The transmitter and reciever path of GSM system is designed and simulated using MATLAB/SIMULINK with digital filter design tool (FDATool) as shown in Figure 3. In the transmitter path, the ECG signal is generated by using random integer generator block. The GSMK digital modulator is used to modulate the ECG signal and feed to the FIR band pass filter under specialspecifications. This FIR filter use to pass only the non-normal ECG signal. The filterd signal is then upsampled to IF band using RRC filter. The

RF band from GSM tranmitter is send to the channel under 20dB SNR. In the reciever pathe, the down sampling RRC filter is used to decimate the incoming signal from RF to IF band and then feed to the FIR banpass filter to recover and isolate the ECG signal. The recover ECG signal is demodulated by GMSK demodulator which will send to the doctor hand phand for investigation.

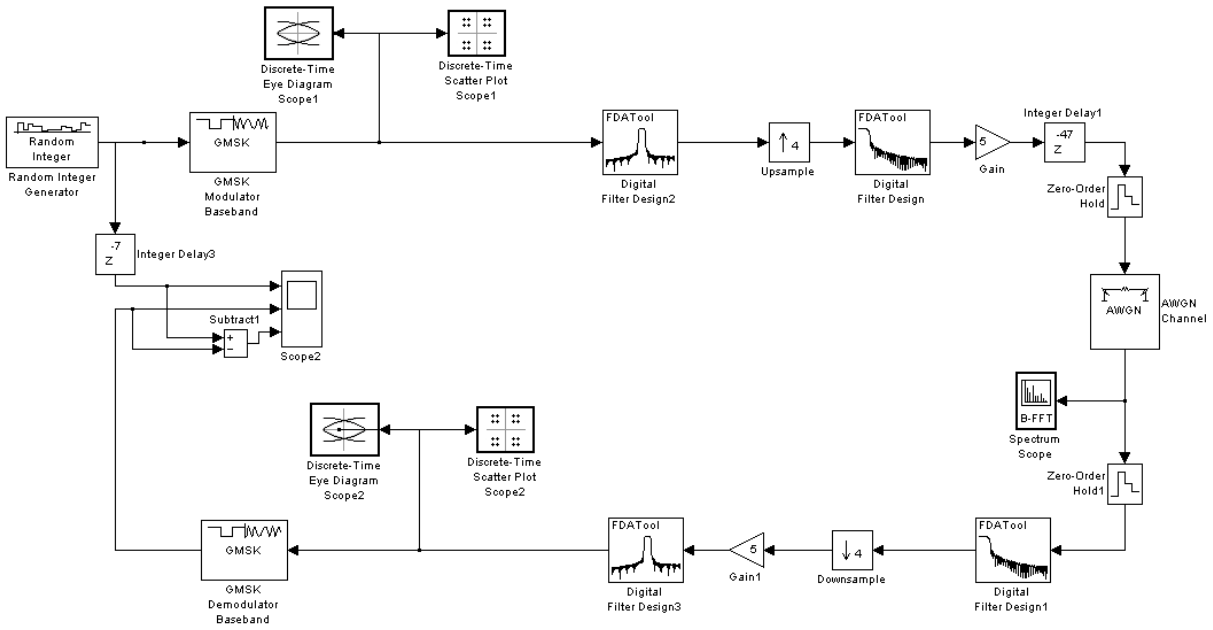
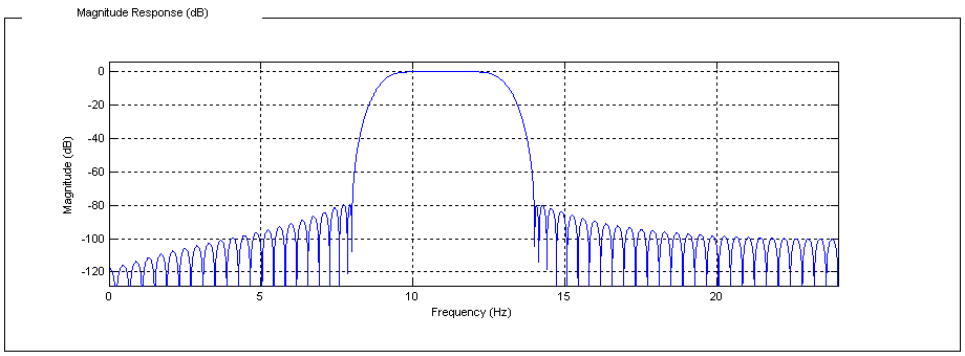


Figure 3: Proposed design of ECG transfer system using MATLAB and FDATool

B. Design of FIR Filter

The desirable characteristics of Kaiser window in the time and frequency domain assist to give time limited function in the ECG signals. The magnitude response of bandpass filter with Kaiser window is illustrated in Figure 4.The filter order is chosen to be 64 with the sampling frequency of 50Hz. The pass-stop band of the designed filter is selected to pass only the ECG signal band from 0.12- 15 second which represent the critical situation of patient. After the ECG signal passed throught the FIR filter, the channel processor increase the signal frequency to intermediate frequency (IF) band by using of so called upsampling filter. The IF band of GSM system in this case is 69.333248 MHz. The FDATool in MATLAB is used to show the frequency and magnitude response of suggested filter. The filter information of all decomposition design provide a linear phase and high stability in the band of ECG signal.



Figur 4: magnitude response of FIR RRC filter

The FDATool enviroment in MATLAB and the signal processing toolbox is used to provide a decmposition design for many advanced techniques assistance. The FIR filter specifications shown in Table 1 is recognized in this paper to work in the GSM transciever as pulse shaping filter after modulation process. The filter performance in term of impulse, magnitude and phase response of proposed filter shows a linear and constant response with respect to digital filter rols which is mean hight stabilty in the band of interest as illustrated inFigure 5, Figure 6and Figure 7 respectively. The power spectrum of transmitted waveform is illustrated in Figure 8 as close as possible to ECG signal.

Table 1: FIR Filter specifications

Parameters	**Specifications**
Response Type	*Bandpass*
Design Method	*FIR Window*
Filter Order	*64*
Scale Passband	*Kaiser*
Sampling Frequency (Fs)	*48 Hz*
First stopband (Fstop 1)	*8 Hz*
First passband (Fpass 1)	*8.5 Hz*
Second stopband (Fstop 2)	*9 Hz*
Second passband (Fpass 2)	*9.5 Hz*
Filter stability	*Stable*
Linear phase	*Yes*

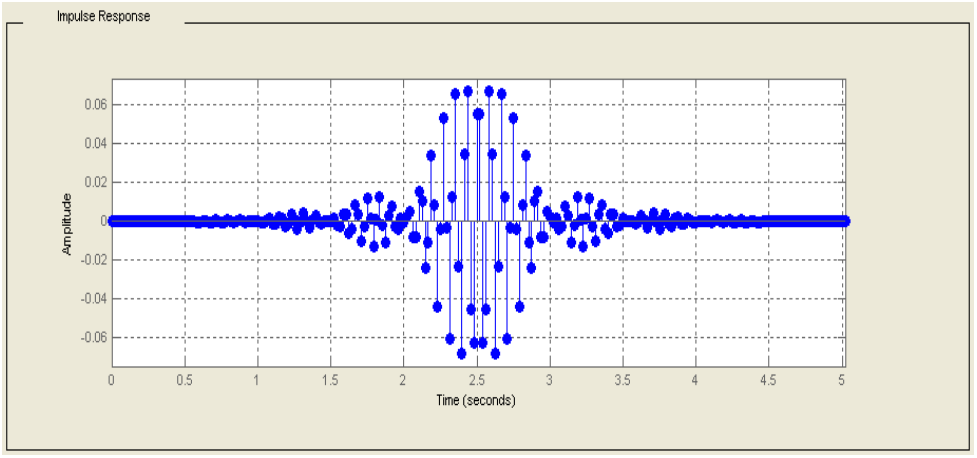


Figure 5: FIR Impulse response

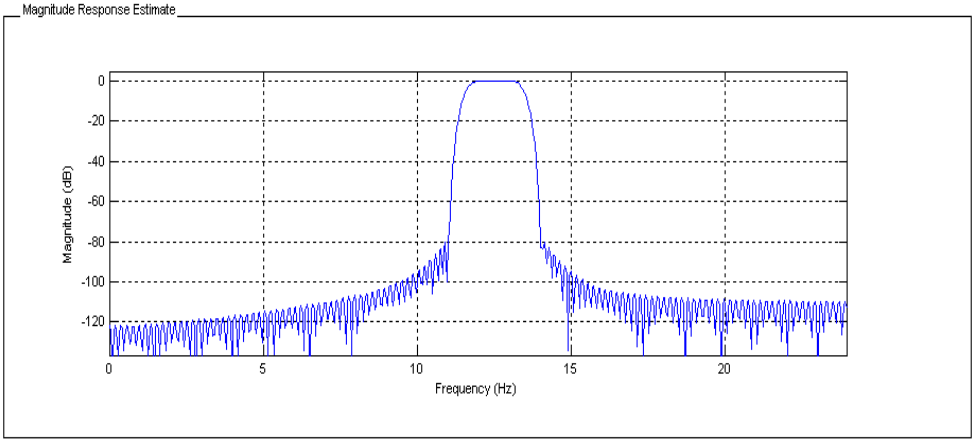


Figure 6: FIR Estimated magnitude response

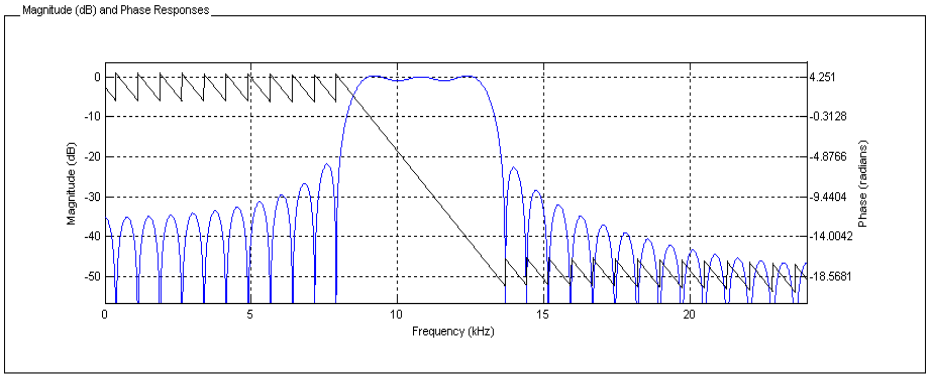


Figure 7: FIR magnitude and phase response

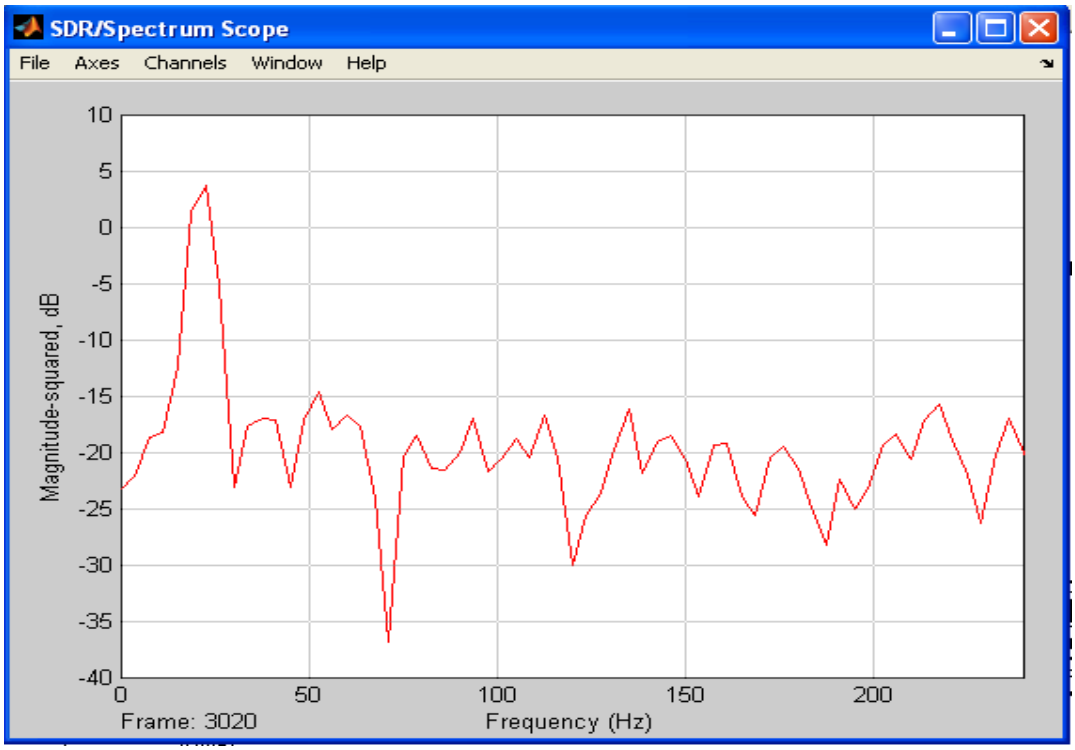


Figure 8: Power spectrum of transmitted signal

II. FPGA Implementation

The GSM transcievers with FIR filter is designed and iplemented in FPGA Vertex-4 to verify the filter perfomance in real time.The implementation and useful confirmation of the proposed FIR filter is concluded by resolve the Xilinx system generator and ISE programs with FPGA virtex 4. The hardware description language (HDL) code is generated by using the ModelSim software and the synthesis step is done using simplify pro from simplicity. The implementation design flow illustrated in Figure 9[15] is used to satisfy the FPGA performance and requirements as well. The project design and synthesis using Xilinx supported schematic is implemented by HDL for text based entry. The HDL file is synthesis into EDIF file and NGC file. In this case, the logical design format in EDIF is converted into physical file format. The native circuit description file NCD for FPGA to generate the bitsteam file from these files in order to optionally program the PROM for following programing into Xilinx FPGA. To ensure the design meet a timing requirements and function properly, the gate level simulator is used for design verification.

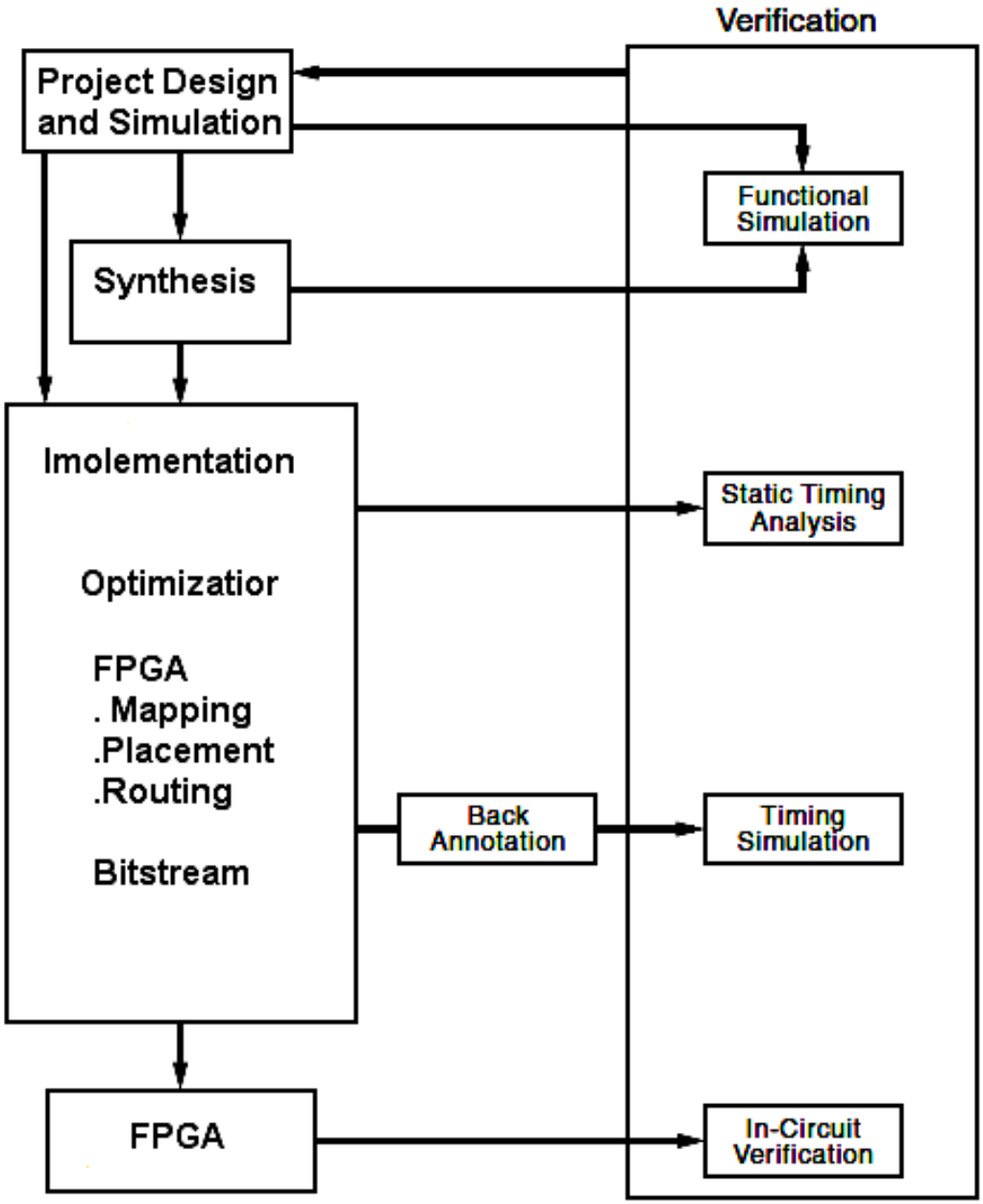


Figure 9: FPGA design flow [14]

Table 2 illustrate the devices summary that used in the proposed system given by ISE programs. The FPGA area consumption in term of slices and LUT in the project implementation shows an important reduction in the FPGA required area compared with current design. The consume elements of used logic number to the available logic elemnts could be calculated using the following formula:

Table2 : Device utilization summary

Device Utilization Summary				
Logic Utilization	**Used**	**Available**	**Utilization**	**Note(s)**
Number of Slice Flip Flops	890	30,720	3%	
Number of 4 input LUTs	745	30,720	2.5%	
Logic Distribution				
Number of occupied Slices	742	15,360	5%	
Number of Slices containing only related logic	710	332	21%	
Number of Slices containing unrelated logic	22	332	7%	
Total Number of 4 input LUTs	433	30,720	1%	
Number used as logic	731			
Number used as Shift registers	104			
Number of bonded IOBs	73	448	16%	
Number of BUFG/BUFGCTRLs	6	32	18%	
Number used as BUFGs	6			
Number used as BUFGCTRLs	0			
Number of FIFO16/RAMB16s	6	192	3%	
Number used as FIFO16s	0			
Number used as RAMB16s	6			
Number of DSP48s	6	192	3%	
Total equivalent gate count for design	275,160			
Additional JTAG gate count for IOBs	3,024			

Conclusions

This paper presents, the most important process to the critical situation of heart patients. The main advantage of the proposed system is the early detection of cardiac disorder of the patients for immediate treatment. When the time interval of ECG signal exceed the normal case, an alert of call or SMS is transmitted throught GSM system to the doctor or nurse hand phone to sought for saving the patient life by prompt medicines. Futhermore, new cellular access technology such as 4G provide much higher data transmission speed which will support the proposed system in terms of time and data size. Consequently, the implementation of ECG transciever using GUI on personal computer is successful with high resolution. The implementation results provide an important utilization in the Slices and LUT via FPGA resources compared with conventional system design.

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