International Journal of Electrical, Electronics and Computer Engineering **3**(2): 34-41(2014)

ISSN No. (Online): 2277-2626

ECG Compression using Discrete Wavelet Transform with Coiflets and Daubechies Wavelets

Anamika Verma* and Vasim Khan**

**PG Scholar, Department of Electronics and Communication Engineering,*
Vikrant institute of technology, Indore, (MP) India
***Associate Professor, Department of Electronics and Communication Engineering,*
Vikrant institute of technology, Indore, (MP) India

(Corresponding author: Anamika Verma)
(Received 05 April, 2014 Accepted 04 July, 2014)

ABSTRACT: This article presents the ECG compression technique using wavelet transform corresponds to the Coiflets and Daubechies wavelets. There are so many techniques are popular for ECG compression. The wavelet based techniques are most popular and conveniently implementable. Here in this paper, we have performed the ECG compression using the lossless coding technique. Further we have analyzed the results for the Coiflets and Daubechies wavelets families, on the basis of different parameters i.e. PRD, Compression Ratio and finally the conclusion is made from the obtained results, which are given in this paper.

Keywords: **Root mean square difference (PRD), Compression ratio (CR), discrete wavelet transforms (DWT)**

I. INTRODUCTION

The "Electrocardiogram" (ECG) signal is a recording of the electrical activity of the heart over time produced by an electrocardiograph and is a well-established diagnostic tool for cardiac diseases [1]. ECG signal is monitored by placing sensors at defined positions on chest and limb extremities of the subject. Each heart beat is caused by a section of the heart generating an electrical signal which then conducts through specialized pathway to all parts of the heart.

The ECG is an invaluable tool for diagnosis of heart diseases. The volume of ECG data produced by monitoring systems can be quite large over a long period of time and ECG data compression is often needed for efficient storage of such data [2].

In a similar sense, when ECG data need to be transmitted for telemedicine applications, data compression needs to be utilized for efficient transmission [3]. While ECG systems are found primarily in hospitals, they find use in many other locales also.

To record ECG signal waveform, a large amount of data should be saved [1-5]. To reduce the space for data storage, some compression must be used, but only if the difference between decompressed - reconstructed signal and the original one is minimal, i.e. if reconstructed signal is not distorted and if cardiologist can obtain the same diagnosis from reconstructed signal as if he would obtain it from original signal [7].

There are several ways to obtain compression of non - stationary signals and almost all of them use transform coding. In the given techniques in this paper the compression of the signal is obtained by Discrete Wavelet Transform (DWT) [8].

The main objective associated with the ECG compression is to obtain the Good compression ratio with the less error after reconstruction and the clear visibility of the ECG component, subjected for the further observation [6-9].

II. ELECTROCARDIOGRAM (ECG)

An electrocardiogram is simply a measure of voltage changes in the body. Any large electrical event can be detected. The electrically-active tissues in the body are the muscles and nerves. Small brief changes in voltage can be detected as these tissues 'fire' electrically.

The heart is a muscle with well-coordinated electrical activity, so the electrical activity within the heart can be easily detected from the outside of the body with the help of ECG. A normal heartbeat or cardiac cycle has P wave, a QRS complex and a T wave. A small U wave is sometimes visible in 50 to 75% of ECGs.

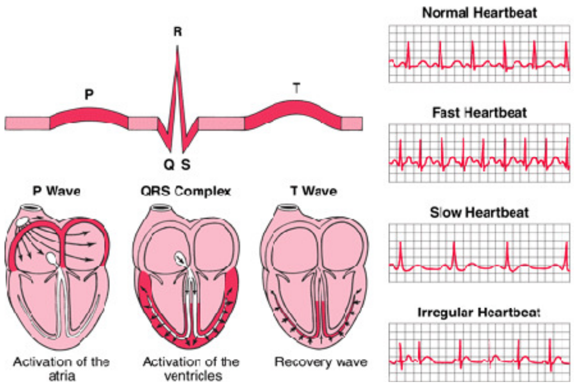

Fig. 1.

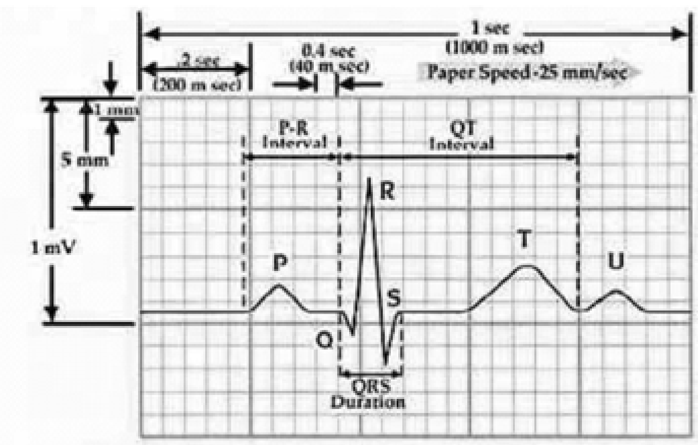

Fig.1. Diagram of a ECG cycle.

III. ECG SIGNAL COMPRESSION

The Data compression can be lossy or lossless. Data reduction of ECG signal is achieved by discarding digitized samples that are not important for subsequent pattern analysis and rhythm interpretation.

The data reduction algorithms are empirically designed to achieve good reduction without causing significant distortion error. ECG compression techniques can be categorized into: direct time-domain techniques; transformed frequency-domain techniques and parameters optimization techniques. In our work we have utilized the parameter optimization technique. We set the optimized PRD before the quantization and encoding of the signal.

IV. PERFORMANCE PARAMETERS

1) Compression Ratio: The compression ratio (*CR*) is defined as the ratio of the number of bits representing the original signal to the number required for representing the compressed signal.

2) Root Mean Square Error: The root mean square error (*RMS*) is used as an error estimate. The *RMS* is given as

$$RMS = \sqrt{\frac{\sum_{n=1}^{N}\left(\mathrm{x(n)} - \bar{\mathrm{x}}\,\mathrm{(n)}\right)^2}{N}}$$

Where $x(n)$ is the original signal, $\hat{x}(n)$ is the reconstructed signal and N is the length of the window over which the *RMS* is calculated.

3) Root-mean-square Difference: The distortion resulting from the ECG processing is frequently measured by the percent root-mean-square difference (*PRD*), which is given by:

$$PRD = \sqrt{\frac{\sum_{n=1}^{N}\left(\mathrm{x(n)} - \bar{\mathrm{x}}\,\mathrm{(n)}\right)^2}{\sum_{n=1}^{N} x^2(n)}}$$

As the PRD is heavily dependent on the mean value, it is more appropriate to use the modified criteria:

$$PRD1 = \sqrt{\frac{\sum_{n=1}^{N}\left(\mathrm{x(n)} - \bar{\mathrm{x}}\,\mathrm{(n)}\right)^2}{\sum_{n=1}^{N}(\mathrm{x(n)} - \bar{\mathrm{x}}\,)^2}}$$

Where $\hat{x}$ is the mean value of the signal [1,2,4-6,8,9].

V. THE DISCRETE WAVELET TRANSFORM

There is a number of time–frequency methods are currently available for the high resolution signal decomposition. But there is many of complexities and drawbacks are associated with them which are minimized in the DWT. The DWT is the appropriate tool for the analysis of ECG signals. The WT improves upon the STFT by varying the window length depending on the frequency range of analysis. This effect is obtained by scaling (contractions and dilations) as well as shifting the basis wavelet.

The key issues in DWT and inverse DWT are signal decomposition and reconstruction, respectively. The basic idea behind decomposition and reconstruction is low-pass and high pass filtering with the use of down sampling and up sampling respectively. The result of wavelet decomposition is hierarchically organized decompositions. One can choose the level of decomposition *j* based on a desired cutoff frequency.

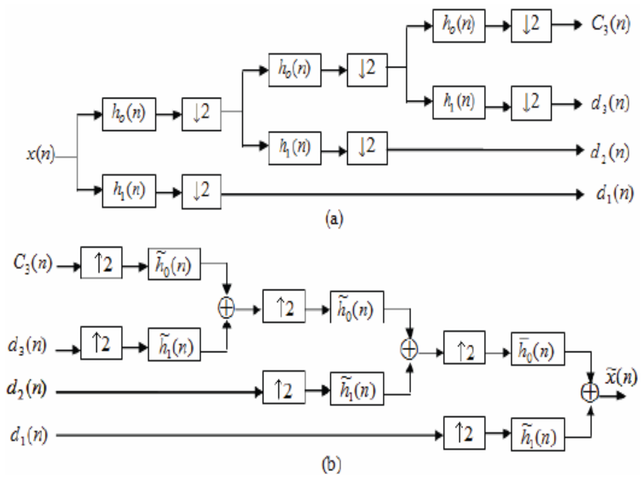

Fig. 3. A three-level two-channel iterative filter bank (a) forward DWT (b) inverse DWT.

VI. DWT BASED ECG COMPRESSION ALGORITHMS

As described above, the process of decomposing a signal *x* into approximation and detail parts can be realized as a filter bank followed by down-sampling (by a factor of *2*). The impulse responses *h[n]* (low-pass filter) are derived from the scaling function and the mother wavelet. This gives a new interpretation of the wavelet decomposition as splitting the signal *x* into frequency bands. In hierarchical decomposition, the output from the low-pass filter *h* constitutes the input to a new pair of filters. This results in a multilevel decomposition. The maximum number of such decomposition levels depends on the signal length. For a signal of size *N*, the maximum decomposition level is log2(*N*).
The process of decomposing the signal *x* can be reversed, that is given the approximation and detail information it is possible to reconstruct *x*. This process can be realized as upsampling (by a factor of *2*) followed by filtering the resulting signals and adding the result of the filters. The impulse responses *h*' and *g*' can be derived from *h* and *g*. If more than two bands are used in the decomposition we need to cascade the structure.

VII. METHODOLOGY

The compression technique proposed in our work is based on the DWT. We obtained the transformed coefficient using DWT and applied the thresholding and obtained the PRD. PRD provides a pre estimation of the overall error in the signal after compression.
Further the threshold is updated until we get the used defined PRD i.e. UPRD. Then we performed the quantization of the obtained coefficients in to the pre decided number of levels.
Finally the thresholded coefficients are coded by Run length encoding followed by Huffman encoding and the significant coefficients are encoded separately using the arithmetic encoding. The compression ratio is evaluated for the compressed signal.
During the reconstruction decoding is performed by the reverse processing. The PRD is calculated for the reconstructed signal that is given as QPRD. The QPRD is compared with the PRD, as it is desired that the PRD should not change more than 10%.
The results are evaluated for the different -different wavelets and the result is tabulated and analyzed.

VIII. RESULTS AND ANALYSIS

We have taken the ECG signal from the well known data base of MIT BIH Arrhythmia. ECG signal (102.dat) is sampled at 360 Hz, so it contains 360 samples per second. We have taken ECG signal, which corresponds to 1028 samples. Each sample corresponds to the 11 bits.
The PRD is the root mean square difference for the signal after thresholding. The QPRD is the root mean square difference of the reconstructed signal after compression. CR is the compression ratio of the compressed ECG.

Table 1. Parameter variation with increasing order of Daubechies wavelets.

Wavelet	Prd	Qprd	CR
db1/Haar	6.4946	6.5886	8.9391
db2	6.4888	6.5648	12.7168
db3	6.4534	6.5554	15.6275
db4	6.4891	6.6019	16.7371
db5	6.4576	6.5342	17.6944
db6	6.4695	6.5782	18.0186
db7	6.4913	6.6238	19.0624
db8	6.4960	6.6693	19.7802
db9	6.4736	6.5660	20.5607
db10	6.4869	6.5930	20.7330
db11	6.4814	6.5953	21.1765

Table 2. Parameter variation with increasing order of Coiflets wavelet.

Wavelet	Prd	Qprd	CR
coif1	6.4521	6.4981	12.2381
coif2	6.4726	6.4992	11.9283
coif3	6.4833	6.5091	11.6337
coif4	6.4980	6.5268	11.1093
coif5	6.4734	6.5244	10.5880

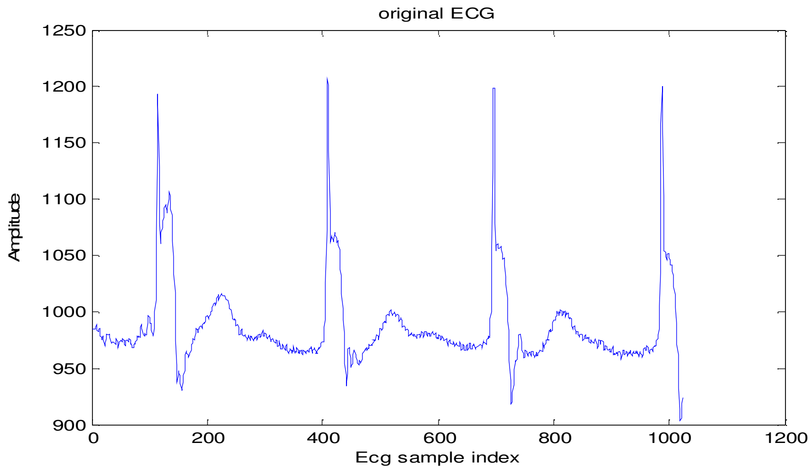

Fig. 4. Original ECG signal.

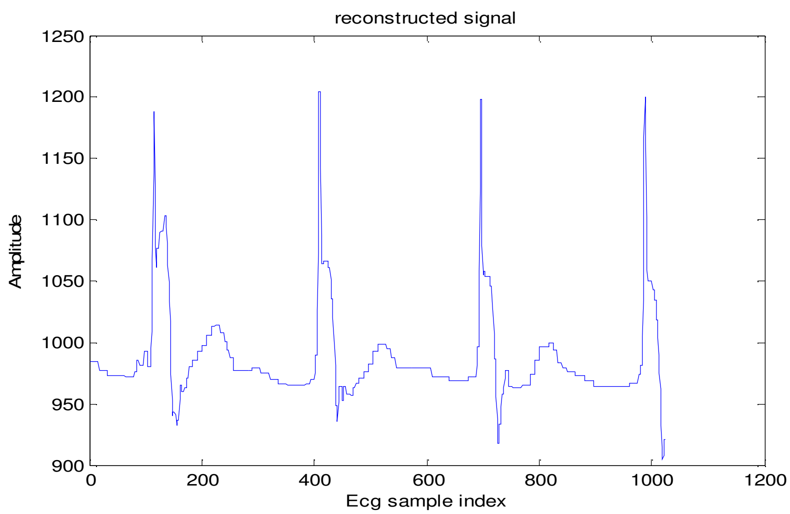

Fig. 5. Reconstructed ECG signal after compression using db1 wavelet.

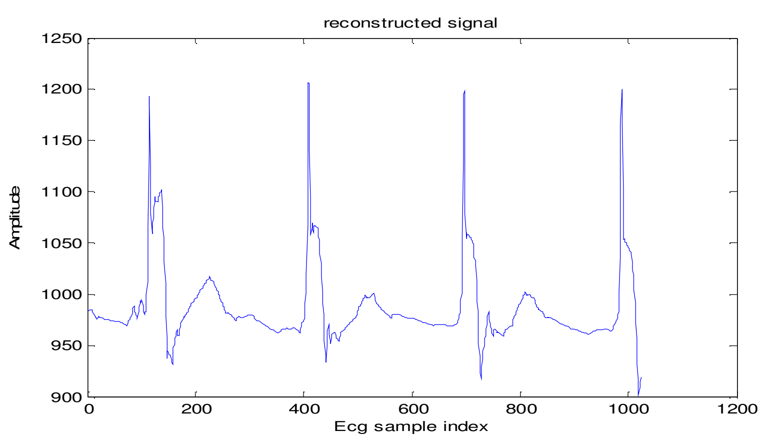

Fig.6. Reconstructed ECG signal after compression using db2 wavelet.

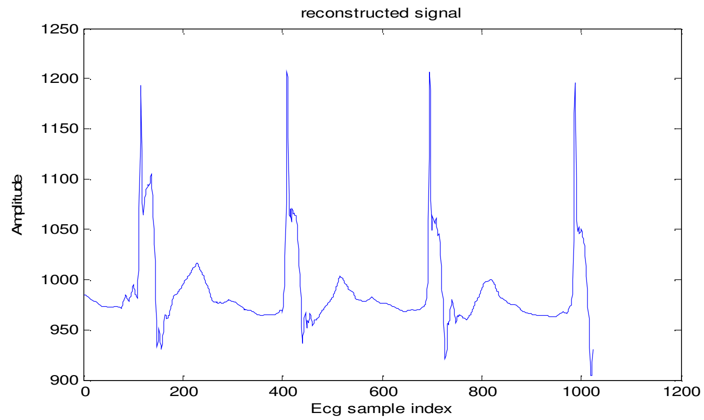

Fig.7. Reconstructed ECG signal after compression using db3 wavelet.

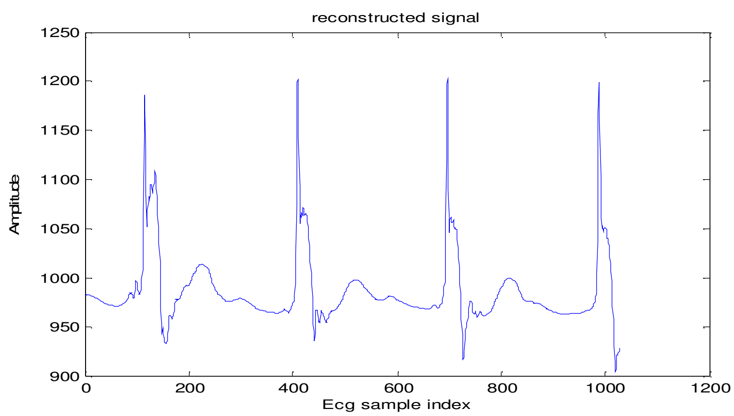

Fig. 8. Reconstructed ECG signal after compression using db4 wavelet.

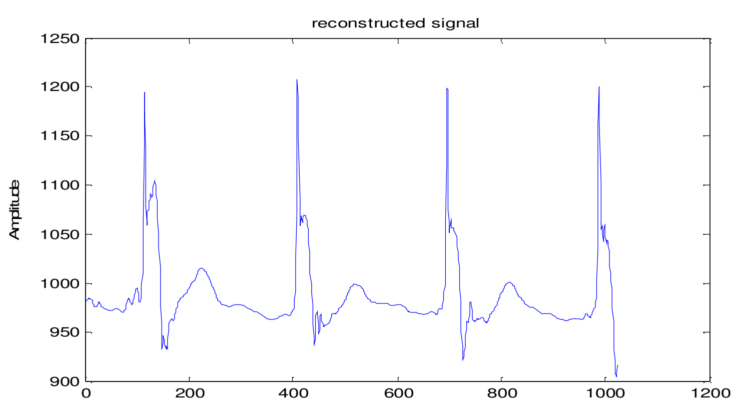

Fig. 9. Reconstructed ECG signal after compression using db5 wavelet.

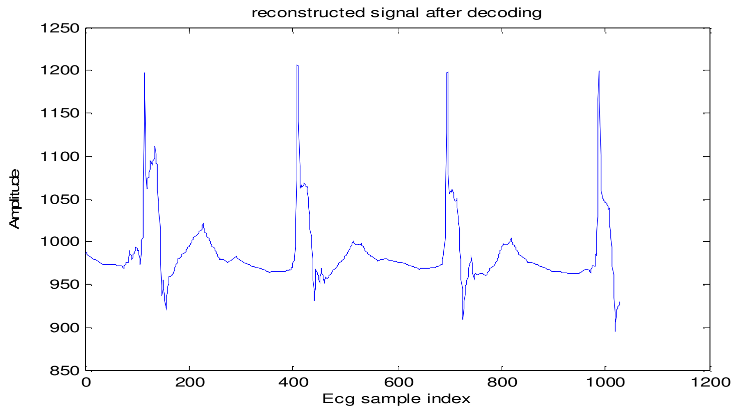

Fig. 10. Reconstructed ECG signal after compression using coif1 wavelet.

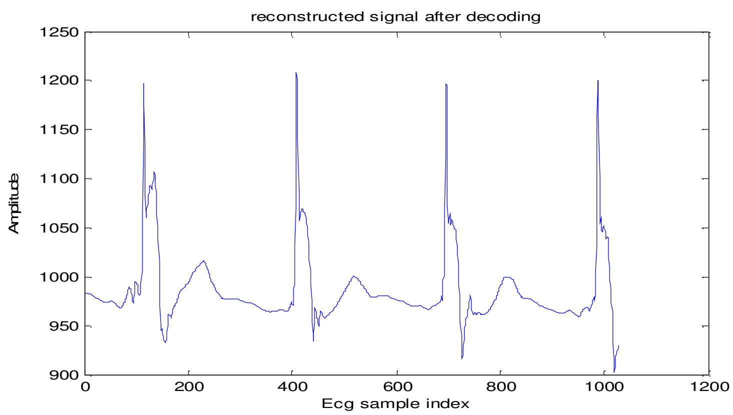

Fig. 11. Reconstructed ECG signal after compression using coif2 wavelet.

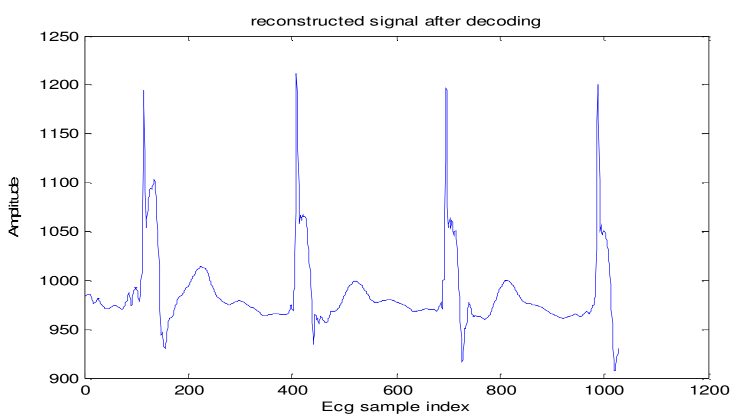

Fig. 12. Reconstructed ECG signal after compression using coif3 wavelet.

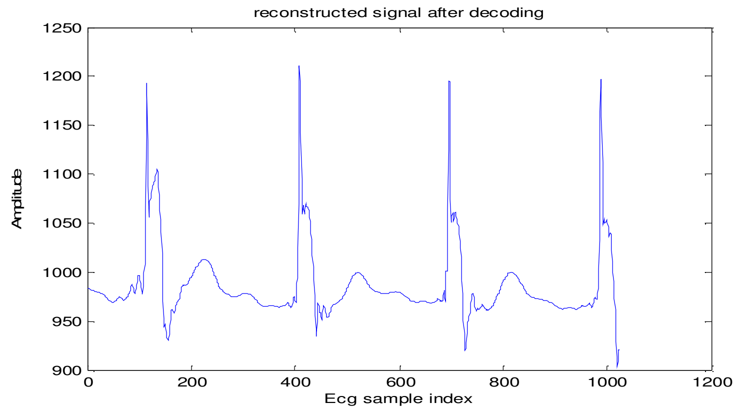

Fig. 13. Reconstructed ECG signal after compression using coif4 wavelet.

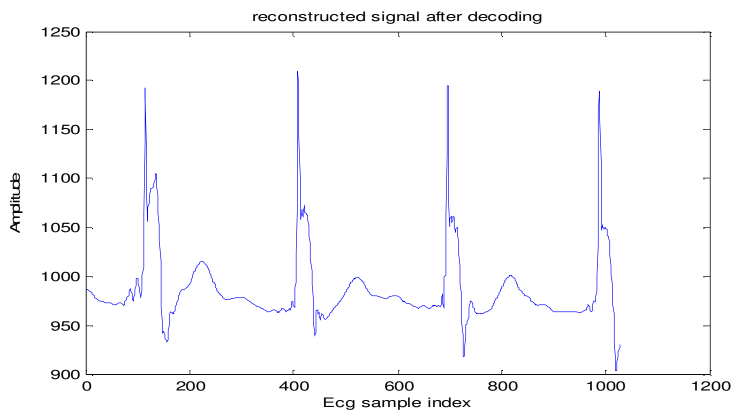

Fig. 14. Reconstructed ECG signal after compression using coif5 wavelet.

From the above results we have found that the compression ratio is increasing with the increment in the order of the Daubechies wavelet and the increment is almost exponential, But the compression ratio is decreasing with the increment in the order of the Coiflets wavelets. Variation in the PRD and QPRD is almost in the permissible range. The difference between two PRD values is less than 0.1 or 10% for all the wavelets as desired.

Yet the shape of the signal is some poor for the very lower order Daubechies as well as Coiflets wavelets, but in terms of the signal shape, we are getting improvement with the increment in the wavelet order.

IX. CONCLUSION AND FUTURE WORK

In our study we have seen the ECG compression using wavelet transform for the different wavelets. The results is obtained and analyzed. From the obtained results and by its analysis, we found the conclusion that it is much better to use the higher order Daubechies wavelet for the ECG compression. It is not only good for the signal quality but also beneficial to get higher compression ratio for the compressed ECG signal. The increment is almost exponential, which can results in high improvisation in the compressibility of the algorithm.

But for the Coiflets wavelet its good to use the lower order wavelet for the higher compression ratio but due to the reduction in the signal shape with lowering the order of the wavelet, we need to select a middle order wavelet for the better performance.

In the future we may try to find some other techniques to get more improvisation in the compression ratio and PRD for the ECG signal compression.

REFRENCES

[1]. bo-Zahhad, "ECG data compression using optimal non-orthohttp://www.intechopen.com/books/discrete-wavelet-transforms-theory-and applications/ecg-signal-compression-using-discrete-wavelet-transform

[2]. Sabah Mohamed Ahmed, Anwer Al-Shrouf, Mohammed A gonal wavelet transform" , *Medical Engineering & Physics*, vol.**22**, pp.39–46, 2000.

[3]. Mohammed Abo-Zahhad, Sabah M. Ahmed & Ahmed "ECG Signal Compression Technique Based on Discrete Wavelet Transform and QRS-Complex Estimation", *Signal Processing – An International Journal (SPIJ)*, vol. **4**, Issue 2.

[4]. Siniˇsa Ili´c, "Comparison of Compression Ratios for ECG Signals by Using Three Time-Frequency Transformations", *SER.: ELEC. ENERG.* vol. **20**, no. 2, pp. 223-232, August 2007.

[5]. R.V.S. Shastri, K. Rajgopal, "ECG compression using wavelet transform", *Proceeding RC IEEE-EMBS*, 1995.

[6]. Anubhuti Khare, Manish Saxena, Vijay B. Nerkar, "ECG Data Compression Using DWT", *International Journal of Engineering and Advanced Technology (IJEAT)* ISSN: 2249 – 8958, vol. **1**, issue-1, October 2011.

[7]. Karishma Qureshi, Prof. V. P. Patel, "Efficient Data Compression of ECG signal Er.Abdul Sayeed, " ECG Data Compression Using DWT & HYBRID", *IJERA*, vol. **3**, issue 1, pp.422-425, January -February 2013.

[8]. Vibha Aggarwal, Manjeet Singh Patterh "ECG Compression using Wavelet Packet, Cosine Packet and Wave Atom Transforms", *International Journal of Electronic Engineering Research*, ISSN 0975 – 6450, vol. **1**, no. 3, pp. 259–268, 2009.

[9]. Priyanka, Indu Saini, "Analysis ECG Data Compression Techniques-A Survey Approach", *International Journal of Emerging Technology and Advanced Engineering*, vol. **3**, issue 2, February 2013.