ECG Signal Compression using efficient transformations

Abhishek Kumar Agrawal
Department of Electronics and Telecommunication Engineering
Bhilai Institute of Technology, Durg, Chhattisgarh, India

Alka Mishra
Department of Electrical and Electronics Engineering
Bhilai Institute of Technology, Durg, Chhattisgarh, India

Dr.Ramesh Kumar
Department of Computer Science Engineering
Bhilai Institute of Technology, Durg, Chhattisgarh, India

Abstract:- ECG is a standard tool to monitor heart function. ECG generated waveforms are used to find patterns of irregularities in cardiac cycles in patients. In many cases, irregularities evolve over an extended period of time that requires continuous monitoring. However, this requires compression of ECG signals. In the past decades, many compression methods have been proposed. In this paper a comparative analysis of Fast Fourier Transform (FFT), discrete sine Transform (DST), and Discrete cosine Transform (DCT) based approach is carried out with good compression ratio and less computation time. To generalize transform based techniques, Tachycardia data base recording which have larger information content are compressed .The appropriate use of a block based DCT associated to a uniform scalar dead zone quantiser and arithmetic coding show very good results, confirming that the proposed strategy exhibits competitive performances compared with the most popular compressors used for ECG compression.

Keywords – ECG, Compression ratio (CR), DCT-II DCT, DST, and FFT.

I. INTRODUCTION

The practical importance of ECG data compression has become evident in many aspects of computerized electrocardiography including: **a)** increased storage capacity of ECG's as databases for subsequent comparison or evaluation, b) feasibility of transmitting real-time ECG's over the public phone network, c) implementation of cost effective real time rhythm algorithms, d) economical rapid transmission of off-line ECG's over public phone lines to **a** remote interpretation center, and e) improved functionality of ambulatory ECG monitors and recorders[1]. In a medical environment, there are several signals which must be constantly or periodically supervised. Some of the most common are the temperature, the concentration of oxygen in blood, the arterial pressure or the electrocardiogram waveform. It is under this scenario that this thesis is developed. In this case, there is an implemented system of acquisition of electrocardiogram (ECG) signals, which must be wirelessly and error-free sent to the required medical location. 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. Similarly, when ECG data need to be transmitted for telemedicine applications, data compression needs to be utilized for efficient transmission.

A growing area of use for ECG is the 24-hour holters that are leased by consumers. These portable ECG devices record and store the data for subsequent interpretation by a doctor. The idea of represent is signal/information in fewer bits and any signal that contains some redundancy can be compressed. The main goal of any compression technique is to achieve maximum data volume reduction while preserving the significant signal morphology features upon reconstruction. Conceptually, data compression is the process of detecting and eliminating redundancies in **a** given data set. Compression relies on the fact that the data is redundant, that till some extent it was generated following some rules and that we can learn those rules, and thus predict accurately the Data. A compressor can reduce the size of a file by Deciding which data is more frequent and assigning it less bits than to less frequent data.

II. Proposed Algorithm

A. Fast Fourier Transform (FFT)–

A fast Fourier transform (FFT) is an efficient algorithm to compute the discrete Fourier transform (DFT) and it's inverse. There are many distinct FFT algorithms involving a wide range of mathematics, from simple complex-number arithmetic to group theory and number theory. A DFT decomposes a sequence of values into components of different frequencies but computing it directly from the definition is often too slow to be practical. An FFT is a way to compute the same result more quickly. Computing a DFT of *N* points in the naive way, using the definition, takes O(*N*2) arithmetical operations, while an FFT can compute the same result in only O(*N* log *N*) operations. The difference in speed can be substantial, especially for long data sets where *N* may be in the thousands or millions—in practice, the computation Fast Fourier Transform is a fundamental transform in digital signal processing with applications in frequency analysis, signal processing etc. The periodicity and symmetry properties of DFT are useful for compression. The *uth* FFT coefficient of length *N* sequence {*f(x)*} is defined as:

$$F(u) = \sum_{x=0}^{N-1} f(x)\, e^{-j2\pi ux/N}$$

And its inverse transform is calculated fro

$$F(x) = \frac{1}{N}\sum_{u=0}^{N-1} f(x)\, e^{j2\pi ux/N}$$
$$x = 0,1,\ldots,(N-1)$$

Time can be reduced by several orders of magnitude in such cases, and the improvement is roughly proportional to *N* / log (*N*).

B. Discrete Sine Transform (DST)–

Discrete sine transform (DST) is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using a purely real matrix. It is equivalent to the imaginary parts of a DFT of roughly twice the length, operating on real data with odd symmetry (since the Fourier transform of a real and odd function is imaginary and odd), where in some variants the input and/or output data are shifted by half a sample. Like any Fourier-related transform, discrete sine transforms (DSTs) express a function or a signal in terms of a sum of sinusoids with different frequencies and amplitudes. Formally, the discrete sine transform is a linear, invertible function *F*: R*N* -> R*N* (where R denotes the set of real numbers), or equivalently an *N* × *N* square matrix. There are several variants of the DST with slightly modified definitions. The *N* real numbers *x0,…, xN-1* are transformed into the *N* real numbers *X*0, ..., *XN*-1 according to:

$$X_k = \sum_{n=0}^{N-1} x_n \sin\left[\frac{\pi}{N+1}(n+1(k+1))\right] \qquad \#$$
$$k = 0,1,\ldots,(N-1)$$

C. Discrete Cosine Transform (DCT)-

The Discrete Cosine Transform (DCT) was developed to approximate Karhunen-Loeve Transform (KLT) when there is high correlation among the input samples, which is the case in many digital waveforms including speech, music, and biomedical signals [3].

The DCT **v**= [*v0 v1…………vN-1*]T
of the vector **x** is defined as follows:

$$v_0 = \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} x_n$$

$$v_k = \sqrt{\frac{2}{N}} \sum_{n=0}^{N-1} x_n \cos \frac{(2n+1)k\pi}{2N}$$

$$k = 1,2,\ldots\ldots(N-1)$$

Where Vk is the k^{th} DCT coefficient. The inverse discrete cosine transform (IDCT) of v is given by

$$x_n = \frac{1}{\sqrt{N}} v_0 + \sqrt{\frac{2}{N}} \sum_{k=1}^{N-1} v_k \cos \frac{(2n+1)k\pi}{2N}$$

$$n = 0,1,2,\ldots\ldots(N-1)$$

There exist fast algorithms, Order (N log N), to compute the DCT .Thus, DCT can be implemented in a computationally efficient manner. Two recent image and video coding standards, JPEG and MPEG, use DCT as the main building block.

III. Experiment and Result

The data from MIT-BIH database is used to test the performance of the coding schemes. This database is sampled at 333Hz, and the resolution of each sample is 11 bits/samples. The amount of compression is measured by CR and the distortion between the original and reconstructed signal is measured by PRD. Table shows the result of the Sinus Tachycardia patient's Electrocardiogram signal. In this table three different compression techniques are used and the analysis of these three techniques is based on five different performance parameters as discussed earlier.

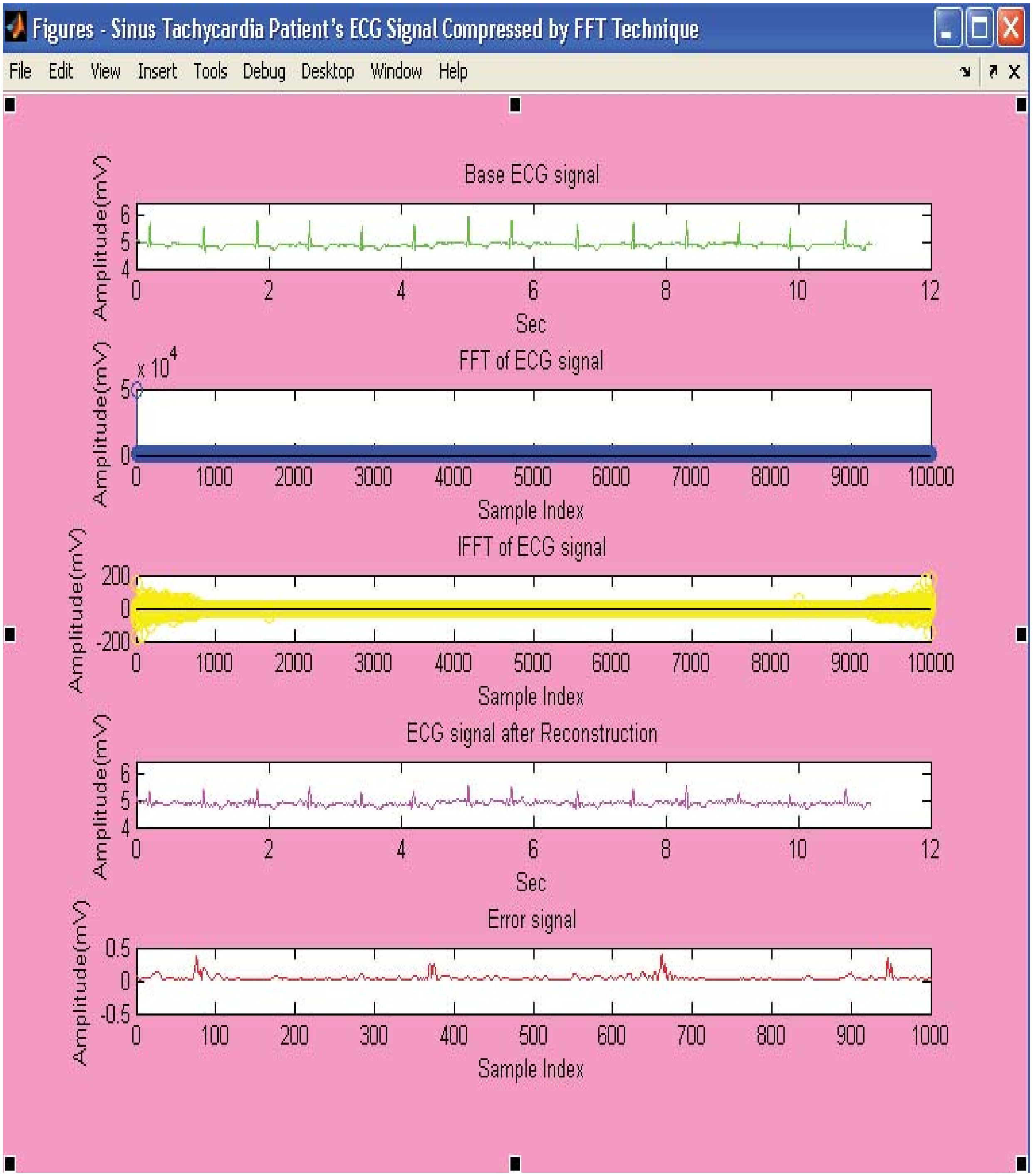

Fig. 1.1: Result of the tachycardia Patient's ECG Signal Compressed by FFT Technique

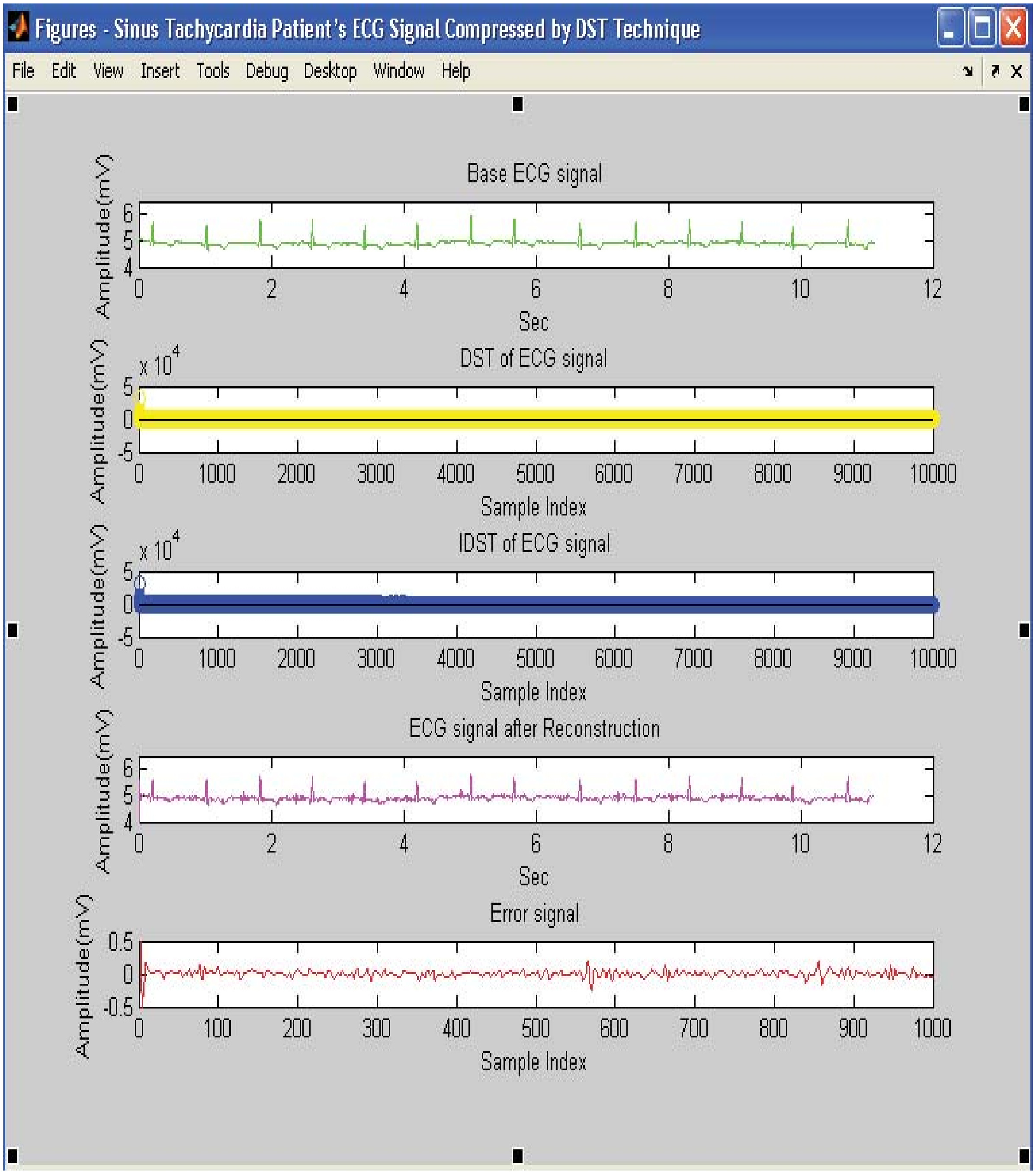

Fig. 1.2: Result of the tachycardia Patient's ECG Signal Compressed by DST Technique

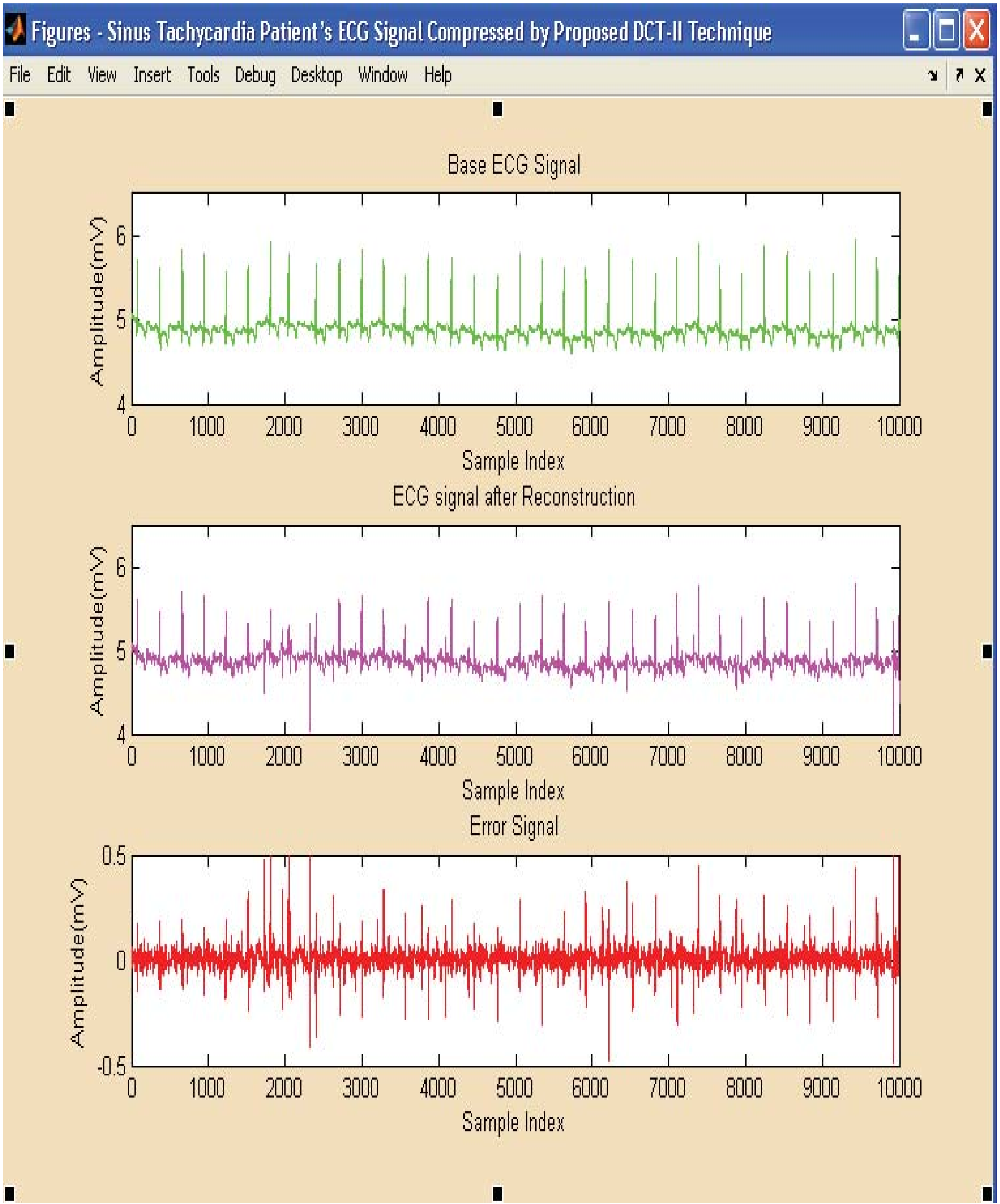

Fig. 1.3: Result of the tachycardia Patient's ECG Signal Compressed by DCT Technique

Table: Result of the Tachycardia patient's ECG Signal

Compression Technique	*CR(compression Ratio)*	*CF(Compression Factor)*	*SP(Saving Percentage)*	*PRD(Percentage Root mean square Difference)*	*CT(Compression Time)*
FFT	*93.9900*	*0.0106*	*6.01*	*1.2105*	*5.3779*
DST	*86.6700*	*0.0115*	*13.33*	*1.1996*	*5.4758*
DCT	*93.9700*	*0.01*	*6.03*	*1.0185*	*5.43*

IV.CONCLUSION

A comparative study of transformation based ECG data compression techniques is carried out and following inferences are

1. DST algorithm obtained low PRD value, high SP and less compression ratio.
2. FFT algorithm obtains less SP than DST but low CR.
3. DCT algorithm achieves higher CR with low PRD value than FFT, but CT is high.

Simulation results have been conducted by using the signal data selected from Tachycardia database and transformation techniques are tested. It is shown that the ECG compression using DCT algorithm can achieve the better compression performance than DST and FFT compression algorithms.

REFERENCES

[1] Francisco N. C., Rodrigues N. M. M., da Silva E. A. B., Carvalho M. B., de Faria, S. M. M., da Silva V. M. M. October 2010. Scanned Document Encoding Using Multiscale Recurrent Patterns, IEEE Transactions on Image Processing, 19(10), pp. 2712

[2] Carvalho, M.B., da Silva, E. A. B. October 1999. A Universal Multi-dimensional Lossy Compression Algorithm, IEEE International Conference on Image Processing Kobe, Japan, pp 225-228. F. Gonzalez and J. Hernandez, " A tutorial on Digital Watermarking ", In IEEE annual Carnahan conference on security technology, Spain, 1999.

[3] Fira Catalina Monica and Goras Liviu. 2008. An ECG Signals Compression Method and Its Validation Using NNs, IEEE Transactions on Biomedical Engineering, vol. 55, No. 4, pp. 1319-1326.

[4] Addison Paul S., Watson J. N., Clegg G R, Steon P A & Robertson Colin E. 2002. Finding Coordinated Atrial Activity During Ventricular fibrillation using wavelet decomposition, IEEE Engineering in Medicine and Biology, pp 58-61.

[5] Ahmed N., Natarajan T. and Rao K. R. 1974. Discrete Cosine Transform, IEEE Trans. Trans. On Computers. C-23, 90-93..

[6] Abdelaziz Ouamri, " ECG Compression method using Lorentzia function model", Science Direct, Digital Signal Processing 1.7 (2007),8th August 2006

[7] Pushpendra Singh, Om Prakash Yadav, Yojana Yadav ECG Signal Compression Validation by a New Transform Technique, International Journal of Innovative Technology and Exploring Engineering (IJITEE) Volume-1, Issue-4, September 2012

[8] Furht B, Perez A. 1988. An adaptive real-time "ECG compression algorithm with variable threshold". IEEE Transaction BME, pp 494–498

[9] Emran Mohammad Abu Anas, Md. Iftekhar Hossain, Md. Shah Afran and Shehrin Sayed. Compression of ECG signals exploiting correlation between ECG cycles, 6th International Conference on Electrical and Computer Engineering ICECE 2010, 18-20 December 2010, Dhaka, Bangladesh .

[10] Om Prakash Yadav, Vivek Chandra, Pushpendra Singh, Design and Analysis of an efficient Technique for Compression of ECG Signal , International Journal of Soft Computing and Engineering (IJSCE) Volume-1, Issue-5

Amita A.Shinde, Pramod Kanjalkar The Comparison of Different Transform Based Methods for ECG Data Compression, Proceedings of 2011 International Conference on Signal Processing, Communication, Computing and Networking Technologies (ICSCCN 2011)