Handheld 12-channel Tele-ECG Machine

Vineet Sinha, R.K. Jain, Sadhana A. Mandalik, Gopal Joshi, D. Das and C.K.Pithawa
Electronics Division, Bhabha Atomic Research Centre,
Mumbai, India
vinsin@barc.gov.in

Dr. Hemant Haldavnekar
Medical Officer in Charge, Occupational Health Centre,
Bhabha Atomic Research Centre,
Mumbai, India

Abstract - **In India, the ratio of doctors to the rest of the population is significantly low. The situation is rather alarming in rural area where 70% of our population resides with only 25% of doctors. BARC has developed a low-cost handheld 12-channel Tele-ECG machine for providing cardiac care, mainly to the isolated rural population. The mobile network use has the advantage of it's reach to about 80% population. The instrument records all 12 ECG channels simultaneously and generates report in form of an image for transmission to the expert's mobile through Multimedia Messaging Service (MMS) or any other file sharing apps. The device is ideally suited for rural health care to save crucial time normally required to shift the patient to the nearest cardiac centre.**

In city, the congestion at hospitals increases the waiting time and causes discomfort, especially to the patients who are admitted in various wards. This handheld ECG unit can be easily carried to the bedside of the patients and thus eliminates the need of carrying the patient to the ECG room. Besides this, the machine can also be operated through Laptop/Desktop and report can be shared on Local Area Network (LAN). ECG report printout in standard graphical format can be taken out on a blank A4 size paper. This paper summarizes this development.

Keywords - Electrocardiography, Telemedicine, Bluetooth, Mobile network, Rural health.

I. INTRODUCTION

Telemedicine enables a physician or a specialist at one site to deliver health care, diagnose patients, give intra-operative assistance, provide therapy, or consult with another physician or paramedical personnel at a remote site. Though, there is no substitute for face-to-face consultation between a clinician and a patient, there are medical cases that can be managed more efficiently by adopting telemedicine. With this, a patient from rural area can be provided a routine check by mobile phone without regularly commuting to a Hospital. Similarly routine inspections and monitoring can be carried out while the patient is at home, traveling or at work. This also decreases the load on resources of the hospital, which can now cater to more number of demanding patients.

Vast area with varied topography, more than a billion population, high population per physician and majority of the population living in isolated villages, support and justify the need for Telemedicine in our country.

In view of the above and the fact that mobile phones are becoming more and more affordable, BARC has developed a mobile network based low cost 12-Channel Tele-ECG machine that records all the 12 ECG channels simultaneously and generates report in form of an image for transmission to the expert's mobile through Multimedia Messaging Service (MMS) or any other file sharing apps. This saves the crucial time normally required to shift the patient to the nearest cardiac centre. It can also be operated through Laptop/Desktop and ECG report printout in standard graphical format can be taken out on a blank A4 size paper. In city hospital, it eliminates the need of carrying the patient to the ECG room.

II. MOBILE BASED TELE-ECG DEVELOPED AT BARC

An electrocardiogram (ECG) is an electrical recording of the heart and is used for detecting heart diseases. It's an integral part of medical diagnosis providing critical information about the electrical activity of the heart. The history of Electrocardiography folds back to 1889, when Willem Einthoven gave the first evidence of electricity generated by heart in men and animals in 1889 during 1st International Congress of Physiologists in Bale. He obtained the cardio-electrical signals from two arms and left leg with the help of saline solution tubs wired to the input of a String Galvanometer and named this signal as ELECTROCARDIOGRAM.

Various deflections in the ECG waveform are labeled as P, Q, R, S and T points, as labeled in Fig.1.

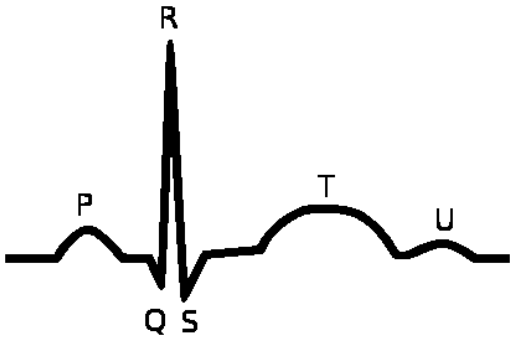

Fig. 1: Typical Lead-II ECG waveform.

P represents the depolarization of right and left atria. Q, R and S as a complex represents onset of depolarization of right and left ventricles. T represents the repolarization of ventricles. The segment following T wave, till the onset of next cardiac cycle, is called iso-electric segment or reference for measurement of amplitude of different waves.

ECG is generally recorded in 12 different configurations of the electrodes placed on the body surface; each configuration is called a 'Lead' or 'Channel'. These are named as I, II, III, aVR, aVL, aVF, V1, V2, V3, V4, V5 and V6, popularly known as Einthoven's Leads as shown in Figure 2.

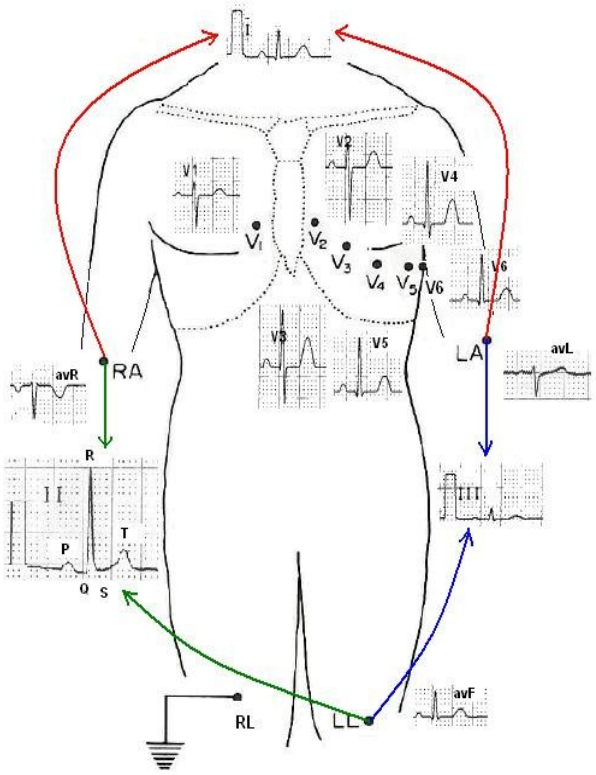

Fig 2. *Anatomical placement of the electrodes and the ECG signal recorded in various configurations.*

III. BLOCK DIAGRAM

Figure 3 shows the block diagram of the 12-channel Tele-ECG machine developed at Biomedical Instrumentation Group of Electronics Division, BARC. The ECG signal from the patient is sensed with the help of 10 surface electrodes labelled as RA (Right Arm), LA (Left Arm), LL (Left Leg), RL (Right Leg), V1(Chest Lead-1), V2 (Chest Lead-2), V3 (Chest Lead-3), V4 (Chest Lead-4), (Chest Lead-5)V5 and V6 (Chest Lead-6). RL is connected to the ground and 12 channels of ECG are derived from different combinations of signals coming from rest of 9 electrodes. These signals are sensed through biopotential electrodes that are transducers that sense ion distribution on the surface of tissue and convert the ion current to electron current. Usually Ag/AgCl disposable electrodes are used as they offer small half-cell potential of approximately 220mV and are easily available commercially.

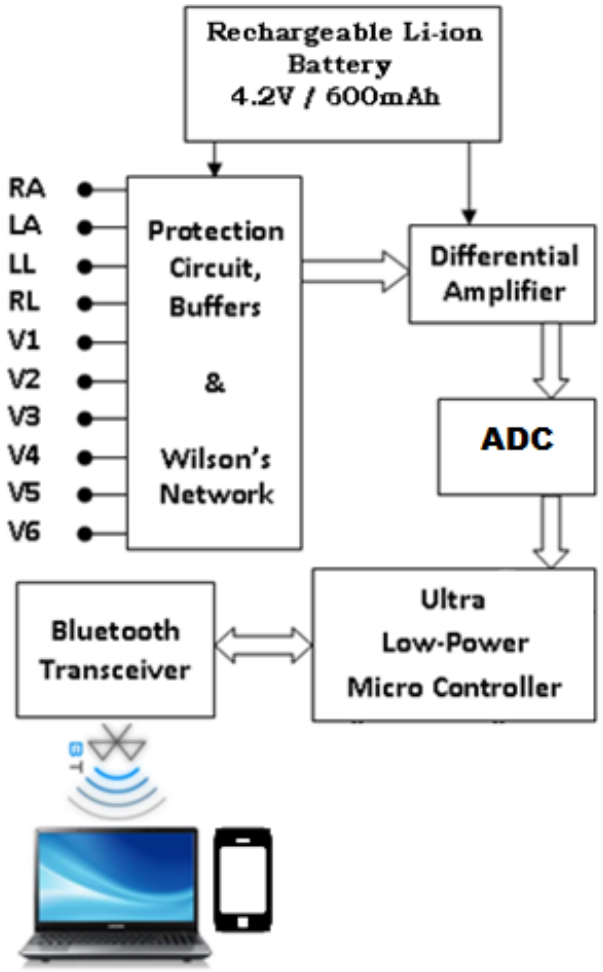

Fig 3. *Block Diagram of the 12-channel Tele-ECG machine*

Patients in the ICU or undergoing surgeries are often connected to other medical equipments. Also machines like defibrillator may be operated onto the patient while the ECG unit is still connected and these high potentials can enter the unit and damage the electronic circuit. Transient Voltage Suppressors protection ICs are used to protect the amplifier IC from large voltages coming from the patient due to application of defibrillator or surgical diathermy.

Signals coming out of protection circuits and buffers are connected to Wilson's network for deriving differential signals for various channels. The Wilson Central Terminal consists of three limb electrodes (RA, LA & LL) connected through a resistor network at the inverting input of the ECG amplifier. It is often used as a zero potential reference in ECG recordings.

The outputs of the buffers are fed to input of the differential amplifiers. The outputs of differential amplifiers are given to inputs of 24-bit sigma-delta ADC. All the inputs are sampled at the rate of 500 samples per second and send to a low power micro-controller through SPI (Serial Peripheral Interface). A Bluetooth controller is interfaced to the micro-controller for transceiving the data, commands etc from the Mobile/PC.

The final specifications of the ECG unit are as follows:

Principle	Bio-potential sensing by surface electrodes
Configuration	Einthoven 12 Leads, Simultaneous
Mode	Test / Patient
Lead Fail Detection	Yes
Gain (User Selectable)	1,2,3,4,6,8 &12
Frequency (User Selectable)	0.05 – 150 Hz 0.05/0.5 – 40 Hz 0.05 /0.5– 25 Hz
CMRR	90 dB
Sampling Rate	500 samples per second
Connectivity	Mobile-Mobile via MMS/Apps Mobile-PC via internet/Bluetooth/USB Unit-Mobile/PC via Bluetooth
Size	3.5”(L) x 2.5”(B)x 0.5”(H) inches
Weight	100 gms
Power Input	+ 3.3V, 150mAH

IV. SALIENT FEATURES

- Significantly low cost instrument as compared to the commercially available instruments.
- Simultaneous acquisition of all the 12-leads
- Battery operated thereby ideal for use in rural area where there are frequent power-cuts.
- Operates on commonly available rechargeable mobile battery.
- Records around 500 ECGs on single recharge.
- Lead Fail Alarm.
- ECG is stored in a digital format for reference for long durations.
- In city hospital; as the instrument is battery operated and small in size, it can be taken to the bedside of the patients and thus eliminates the need of carrying the patient to the ECG room.
- Several ECGs can be taken and stored. Once all ECG has been taken, all data can be transferred to the PC. Usually the city hospitals have LAN and thus all this data gets stored in the database of the patient and is available for future reference.
- The expert can see the report on his/her PC and give comments that will be available to all the doctors throughout the hospital, thus eliminating the need of taking out hardcopy of report for every patient.
- In case hardcopy is required, printout on A4 size paper can be taken from the printer attached to the Mobile/PC. This printout does not fade away with time as in the case of hardcopy from a thermal printer.

V. WORKING METHODOLOGY

Fig 4. 12-channel Tele-ECG machine in operation

Figure 4 shows the actual photo of prototype model (encircled in RED) of 12-channel Tele-ECG monitor. The 10 leads coming out of the instrument are connected to the patient either by standard clamp or spot electrodes. The patients’ details such as Patient Name, ID number, age etc are entered and START button is pressed on Mobile/PC to start the acquisition. The micro-controller sends the digitized samples of 8-channels of ECG namely I, II, V1, V2, V3, V4, V5 & V6. Rest 4 channels (III, aVR, aVL and aVF) of data are derived from these 8 channels of ECG by using the following formulas.

$$III = II - I \qquad aVR = -\frac{(I + II)}{2}$$

$$aVL = I - \left(\frac{II}{2}\right) \qquad aVF = II - \left(\frac{I}{2}\right)$$

To check the proper functioning of the hardware, initially the machine can be operated in Test Mode. Square wave of 1 Hz at I, II, V1, V2, V3, V4, V5 & V6 indicates proper working of the hardware. To record ECG from a patient, the instrument is operated in Patient Mode. Once the START button is pressed, 2.5 seconds data of all the 12-Channels of ECG are displayed on the screen. As and when required user can change the gain and select the desired frequency range. Along with the data, micro-controller also sends status of all the 10 leads which is used to detect Lead Failure and alarm is raised in case of improper connection of any of the 10-leads to the patient’s body. User can view and eliminate improper waveform in any channel that may arise because of non-cancellation of DC offset, improper electrode placement, drying up of electrode gel or noise pick-up from surroundings. Once proper ECG data has been obtained, report can be generated at the click of a button.

Fig. 5 shows a typical report generated from the 12-channel Tele-ECG machine onto a mobile. The report is generated in the form of an image, in PNG format of approximately 30KB size, which can be mailed or shared via any file sharing apps. If required, printout of the report can be taken in 1:1 ration to generate hardcopy in standard graph paper format. The grid size is of 5mm x 5mm with X-scale of 200ms/div and Y-scale of 0.5mv/div. A reference pulse of height 10mm representing 1mv is shown at the starting of the graph for comparison of ECG signal amplitude. The report contains patient details such as name, age, sex, date etc. along with 2.5 seconds data of all the 12-channels and a long lead-II of 10 seconds in simultaneous as well as sequential report format.

If the hospital has a local LAN, this report can be uploaded and the expert can view it from his/her chamber. In case of emergency, if the expert is not available in the hospital, the report can be sent through e-mail, MMS (Multimedia Messaging Service) or any other file sharing app, via a mobile, for the opinion.

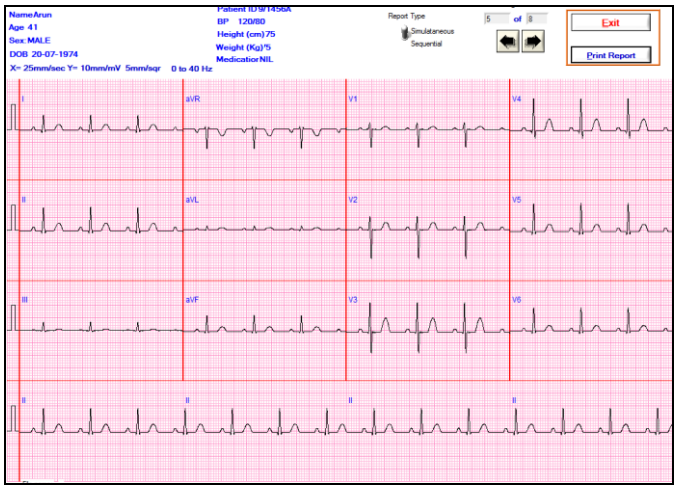

Fig 5. 12-channel simultaneous ECG Report

VI. Results And Discussion

12-Channel Tele-ECG Machine developed at BARC had undergone a thorough lab as well as field trials. At lab, Fluke make multiparameter simulator PS 420 was connected to the machine under different configurations and reports were generated. These reports were analyzed to verify sampling rate, amplitude, heart rate, lead fail detection and other parameters of ECG. The machine has also been tested on several patients at dispensary. The machine was simultaneously connected to the patient along with commercially available Schiller make ECG machine and ECG reports were generated. These reports were carefully compared and analyzed by the doctors and it was certificated that the 12-Channel Tele-ECG Machine can be used for reliable recording and generation of 12-Channel ECG Report.

At present, the machine is ready for technology transfer and more information about it can be obtained from http://www.barc.gov.in/technologies/ecg/ecg.html

VII. Conclusion

The development described above has undergone clinical trials. Efforts are being made to further reduce the size as well as the power consumption so as to increase the battery life. An application, which will lead to a diagnosis of the ECG data, is under development. This information derived from the QRS complex will be used to provide a machine generated unconfirmed diagnosis. Algorithm for Comparison with the commercially available 12-channel ECG machines has shown no significant loss of information and promises a breakthrough in providing a low-cost handy service to the hospitals as well as telemedicine services to isolated rural population.

ACKNOWLEDGMENT

The authors acknowledge help from Smt. Gouri V. Sawant and Shri Ashok D. Kamble in testing and data collection.

References

[1] Hwang S, Lee J, Kim H and Myoungho L (2000): Development of a web based picture archiving and communication system using satellite data communication, J. Telemed. Telecare, Vol. 6, pp 91-96.

[2] Boyd SYN, Bulgrin JR, Woods R, Morris T, Rubal BJ and Bauch TD (2000): Remote echocardiography via INMASAT satellite telephone, J. Telemed. Telecare, Vol. 6, pp. 305-307.

[3] Rasid MFA and Woodword B (2005): Bluetooth telemedicine processor for multi-channel biomedical signal transmission via mobile cellular networks, IEEE Trans. on Inf. Tech. in Biomedicine, Vol. 9, pp. 35-43.

[4] Vineet Sinha, Sandeep Bharade, T.S. Ananthakrishnan, G.D. Jindal, P.K. Mukhopadhyay, R.K.Patil, G.P.Srivastava, A.D. Kamble, Bhagyashree Sarode, P.N. Jangale and Alaka D. Deshpande (2009): Mobile based Tele-ECG for rural health care, BARC Newsletter, No. 301, pp 2-10.

[5] Einthoven W (1901): Un nouveau galvanometer, Arch. Neerl. Sc. Ex. Nat., Vol. 6, pp. 625-633.

[6] Kuhfeld AW (1993): A heart to chart conversation, IEEE Engg., in Med. & Biol. Magazine, Vol. 12, pp. 109-110.

[7] Matthews BHC (1934): A special purpose amplifier, Journal of Physiology, Vol. 93, pp. 25-27.

[8] Myerburg RJ (1981): Electrocardiography, In Harrison's Principles of Internal Medicine, 9th Edition, McGraw-Hill Kogakusha Ltd., pp. 999-1011.