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Wireless Tele Care System for Intensive Care Unit of Hospitals Using Bluetooth and Embedded Technology

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Abstract: The often found problem in the Intensive Care Unit (ICU) of Hospitals is that the physician is unable to be there all the time with patient monitoring equipment to monitor individual patient's biomedical parameters. Also, the nurses in charge of ICU have to be on constant move from patient to patient to monitor the vital parameters. This study proposes a wireless telecare system for the patients at the Intensive Care Unit and the proposed system requires virtually miniscule help from the aiding staff. The primary aim of this study is to establish real time bidirectional communication between the patient, doctor and the nurses' base station in an ICU. Biomedical data such as ECG, heart rate, temperature, drip level, blood pressure of the patient are transmitted to the physician's cabin and nurses' base station using Bluetooth and ARM Technology. Based on the report received, the doctor may prescribe the needed medication for the patient and send it to the nurse base station. The whole system has been implemented and tested. The results obtained are encouraging. The wireless link has been appropriately chosen after careful analysis and study since Bluetooth poses no threat to the patient as such.

Key words: Telecare, ICU, Bluetooth, patient monitoring, ARM processor

INTRODUCTION

Patients with haemodynamically important cardiovascular and respiratory system diseases are usually hospitalized in Intensive Care Units (Paul *et al*., 2000). There they are connected to numerous devices such as ECG, pulse oxymetry, non-invasive blood pressure and invasive monitors which constantly measure the condition of their important physiological parameters. Day in and day out, the physician has to frequently visit the patient and assess his condition by measuring these parameters. In case of emergency, the nurse intimates the doctor on duty by means of mobile phone. This indeed is a time consuming process. This helps neither the patient nor the doctor. The patient is still at the state of risk if his condition is unnoticed. The timely manner of conveying the real time monitored parameters to the doctor is very much needed. Only the doctor will be in a position to analyze the condition of the patient and decide as to what has to be done further to bring the patient back to the stable condition (John,1991). Also, providing constant 24 h per day supervision increases the costs of treatment dramatically. To overcome these problems a wireless telecare system is proposed.

There are several requirements to provide a telecare system for the patients at the ICU ward. First, a wide area of coverage is needed as a backbone to serve the telecare system. Second, the speed and time at which these biomedical parameters are being transferred to the doctor without any distortion of information. Third, the level of interaction needed determines the technology.

Short-Range Wireless (SRW) networks: Short-Range Wireless (SRW) networks such as Bluetooth technology, RFID and IR, are gradually becoming more and more widespread in modern information systems (Bauer *et al*., 2000). Most of these SRW networks have some drawbacks as the transmitting distance is less or else they are prone to disturbance due to outside environment. The most feasible of them all is Bluetooth as it has the essential ingredients whether it be the data rate or the error rate at which it transmits.

Infra Red (IR) is widely used SRW technology but it can transfer at the rate of only 3200 bps and the devices have to be on line of sight for the transfer of information. RFID is another technology but the restriction in this kind is that it is suitable only for 1 or 2 m and it is only a point to point communication. A technology is needed which

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can communicate for longer distances with high data rates and the above all, a master must be able to communicate to more than one slave device. Blue tooth which is a short range wireless technology uses 2.4 GHz frequency range to transmit both voice and data, as packets over the link effectively. It can support simultaneous connections from the hosts which is very much required (Nathan, 2001). Less usage of power and data transfer rate of 721 kbps makes it as a unanimous choice for our system.

OVER VIEW OF WIRELESS TELECARE SYSTEM FOR ICU

A rapidly increasing number of healthcare professionals now believe that wireless technology will provide improved data accuracy, reduce errors and result in an overall improved patient care (Varshney, 2006).

Hence to solve the conundrum posed at the ICU ward, a strategy for wireless telecare system for the patient along bedside is proposed. The telecare system needs to be interactive in both directions. The physician is also needed to send the suggestion back about the patient to the nurses' central station so that the nurse can take immediate action. The system consists of three main blocks: the one at the patients end, another at the physician's end and one at the nurses end as shown in Fig. 1.

A telecare system is constructed such that it measures the biomedical parameters at the patients end without any intervention and then transmits the data acquired to the remote station (base station). This system also accepts the suggestions sent by the doctor at a remote end so that immediate action can be taken. The entire system is portable and consumes low power so that it would not cause much of hindrance to the patient. The device is constructed such that it transmits all the vital parameters of the patient periodically for every 1 min.

The remote PC at the doctors side is equipped with a well-furnished front end, receives and displays the real time data of the patients. The doctor would then analyze the data displayed for each patient and then send the suggestions when required. This method of sending the suggestion back would reduce then fatality rate as suggestion is sent to the nurses end immediately after proper analysis of the data.

DESIGN AND IMPLEMENTATION

Figure 2 shows the handheld device designed to acquire the data from the patient. This is constructed using ARM processor. To transmit the data to the remote PC, Blue tooth USB adapter (dongle) is connected to the USB port of both the handheld device and the remote PC. Multiprocessing is required for the handheld device as it has to transmit the data and acquire it simultaneously. Figure 3 shows the simplified block diagram of the system.

The ARM Processor is the heart of the handheld device. The ARM is a 32-bit machine with a register-to-register, three-operand instruction set. ARM920T core is the most advanced of all the cores available amongst the ARM series. An Atmel product of AT920 architecture, AT91RM920 is used for this purpose. The ARM processor is a 32-bit RISC processor (Dandamudi, 2005). It is designed and developed by ARM Ltd. (Advanced RISC machine). These ARM processors have high performance together with low power consumption and system cost. The ARM920T features instruction and data caches, Memory Management Unit (MMU) enabling support for all major Operating Systems (OS). It is a single development toolkit for reduced development costs and

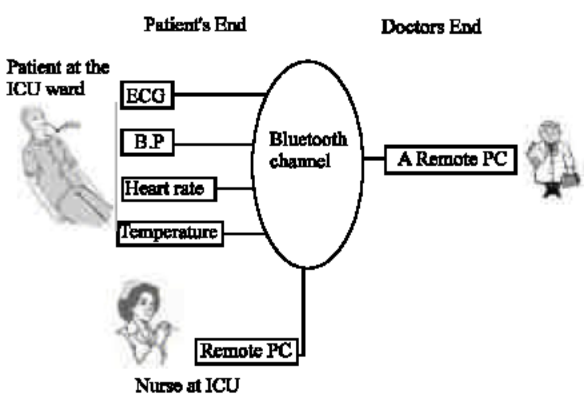

Fig. 1: Over view of wireless telecare system for ICU

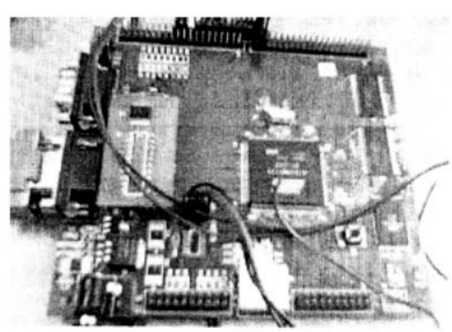

Fig. 2: Handheld device at the patient end

shorter development cycle time. The ARM processor provides solutions for Open platforms running complex operating systems for wireless, consumer and imaging applications. It has wide applications in Embedded real-time systems for mass storage, automotive, Secure applications including smart cards, SIMs, industrial and networking applications (Furber, 2000).

Embedded Linux is the Operating System which runs the AT91RM920. The Embedded Linux has three parts starting from the Boot loader to the Kernel and the RFS (Root File System). U-boot is the boot loader used in AT91 Core and it is burnt in Starting location of the Flash

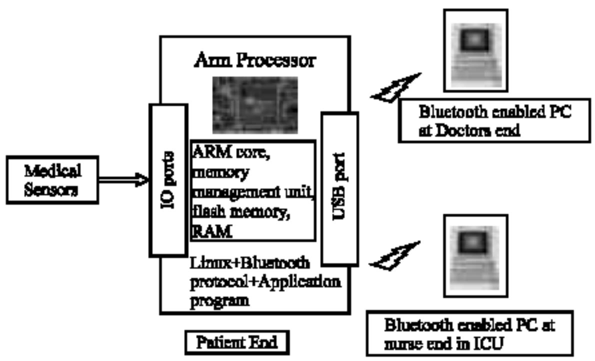

Fig. 3: Basic block diagram of the proposed tele care system

memory. As soon as the handheld device boots, U-boot fetches the Kernel from the Flash and puts it in to the RAM. The kernel then takes the RFS after it loads itself completely. The U-boot is readily available in the net which can be downloaded and fused to the Flash memory. Similar is the case for the Kernel and the RFS but little difficulty arises as it has to comply with and get patched for the specific target (AT91RM920 core in this case). Once the compilation and patching are over, it is ready to be uploaded in the flash itself.

For the purpose of converting the analog data acquired to digital, an ADC 0808 is used. This is further given as input to the parallel port of the AT91RM920 processor. The sensor which would measure the digital data such as drip level could be connected to the processor directly. Signal conditioning circuit is constructed for the SpO2 sensor which would measure the heart rate.

One of the important functions of the kernel is to recognize the hardware connected to it by means of device driver program. The device driver program for the ADC and the rest of the sensors is written in C and compiled along with the kernel. The RFS is the user environment in which the program for acquiring data and transmitting is written. The program is the compiled along with RFS and burnt in the flash after the kernel location.

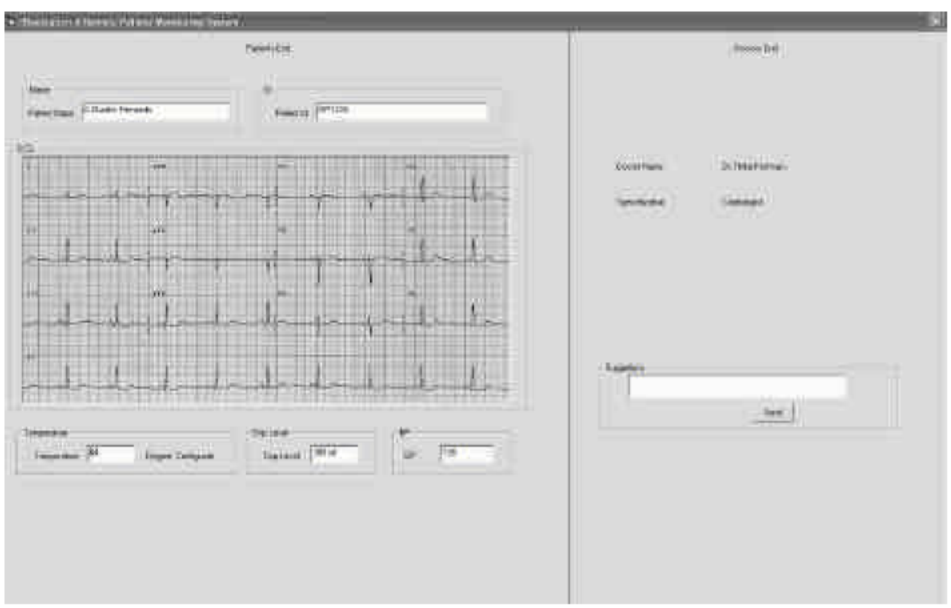

Fig. 4: Front panel display at doctor end and nurse's end showing temperature, drip level, pressure and ECG of the patient in ICU

BlueZ is the official Linux Bluetooth Protocol Stack which is also readily available as a open source over the internet. The protocol stack is also compiled along with the kernel and burnt in the flash. A Bluetooth USB adapter is used as a physical device to transmit the data to the desired location. Each USB adapter has it own unique hardware ID called the MAC ID. Program is written so as to transmit the information only to the desired MAC ID and the rest of the system will ignore it.

An LCD display is also fixed in the device to receive the suggestions from the doctors apart from the bio medical sensors. The appropriate Kernel and FFS level programs are also written and fused in the Flash.

The Base station which would acquire the data is also enabled with a USB Bluetooth Adapter. The handheld device with the patient would transmit the data to the MAC ID of this device alone and ignore the rest. The front end is constructed using visual basic and displays the acquired information and updates it continuously. Front end as shown in the Fig. 4 is spilt into two sections one would display the patients information and the other is for the doctor to send his suggestion back to the handheld device. The handheld device is unique for each patient.

SENSORS

Sensors play an important role in the monitoring of the parameters in the handheld device (Bieliková, 2002). The precision at which the handheld device is to be operated is decided by the sensors in the system. Vital parameters of the patient such as temperature, glucose level, ECG, drip level, pulse rate can be measured. The measured values are then transmitted to the base station via Bluetooth. The sensors have to be designed properly in order to make the handheld device not much prone to erroneous data. The sensors which we have chosen for our system are temperature sensor, drip level, ECG and SpO2 sensor.

Temperature sensor: The temperature sensor is used to measure the body temperature and it is needed to be monitored at constant time intervals. The temperature measured at the handheld device is then sent to the base station. The temperature being measured is analog in nature and hence an ADC0808 is used for acquisition of the data and then for convertion into digital values. The digital values obtained from the ADC are then fed to the ARM processors parallel port for further processing.

The device driver for ADC is written at the kernel level of the linux OS and then a user program actually measures and controls the operation of this sensor. The device driver program is written and compiled in C and then attached along with the kernel through the zImage which has already been mentioned as the compressed linux kernel. The user program for fetching the data and for further maneuvering is also written in C and then compiled along with the RFS. Both these are fused along with the flash memory of the hand held device.

Fig. 5: Float sensors

Float sensor: Figure 5 shows the float sensor used to measure the level of drip in the saline bottle. This is again of prime importance in medication process. The drip once emptied, will indeed feed air to the body which could lead to the death of human being. In order to avoid this from happening, we are using a float sensor which would actually measure the level of drip in the bottle and then transmit it to the base station. When empty, a trigger can be activated which would initialize a relay to cut the down the drip.

The operation of this type of sensor depends on which level of contact it is. When it touches the bottom level is will indicate LOW and the trigger action has to be performed accordingly. The float sensor is indeed a contact based sensor which actually gives the digital value and hence the need for an ADC is eliminated. A user program can efficiently be used for acquisition of the data from the float sensor. The user space program is compiled along with the RFS and then fused along with others in order to transmit the acquired data to the base station.

ECG signal: The ECG signal shown in Fig. 6 is being acquired simultaneously along with other parameters and the received signal is transmitted to the base station. As usual the data is acquired by means of a user program at the root file system which controls the operation.

The data is transmitted to the base station in the format of an image. The transmitted image is then obtained, assembled and then fed to the front end in Visual basic and the doctors use it for further analysis.

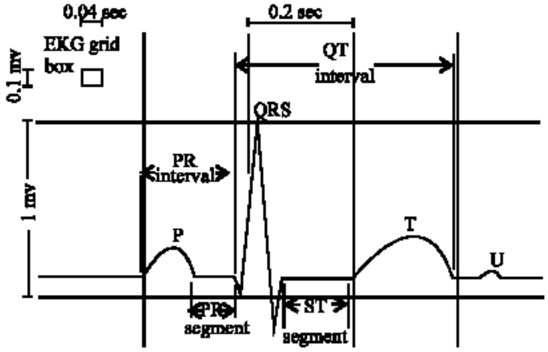

Fig. 6: ECG Signal

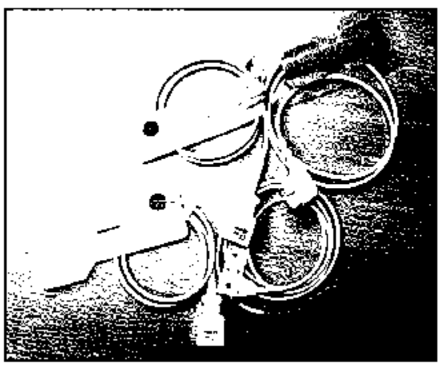

Fig. 7: Pulse oximeter sensor

Pulse oximeter sensors: The heart rate of the patient is measured using the pulse Oximeter sensor as shown in Fig. 7. The operation and type are as follows; basically a two-sided probe transmits infrared light through body tissue, usually a fingertip (Rusch *et al*., 1996). Most light will be absorbed by the tissue between the probe. The small amount of light that is not absorbed is detected by sensors on the other side of the probe and this is used to measure hemoglobin saturation. Absorption variation between oxygen-rich and oxygen-poor produces a difference that enables the microchip to calculate hemoglobin saturation. SpO2 can be measured at any place where a pulse is accessible. In practice, oximeter is usually measured on fingers, the earlobe or with infants at the bridge of the nose.

The sensor types depend on the different applications and usage. Broadly there are two types namely disposable and reusable sensors. We have used reusable sensor since it can be used more than once. The program for fetching the data from the reusable finger probe is written and compiled which is then fused in the flash memory of the ARM processor along with the kernel and RFS.

BLUETOOTH CHANNEL MODELING

After encountering problems in some baseband parameters of our physical hardware implementation, Bluetooth transmission was successfully implemented by building a Simulink model. Although the existing model fully supports transmission of voice packets (HV1, HV2, HV3), it has been extended to include support for the transmission of basic data packets (DM1). The Simulink model relating each of the block components is shown in Fig. 8. The Simulink model is composed of several core blocks to create the simulation of the entire Bluetooth system. System parameters block configure the whole model's packet type, slot pair and channel type. There are two possible channel models: (1) Additive White Gaussian Noise (AWGN) and (2) AWGN with an 802.11 interferer. The Simulink model shows the interplay between the Bluetooth master and slave device. The transmission and reception of the signals are event driven in nature and the algorithms are modeled using state- flow, a finite state machine tool, which defines the device's state as being either "idle", "transmitting", "training", or "synchronizing".

Data transmission: Data transmission uses Asynchronous Connection-less (ACL) packets. Currently, the implementation of data transmission requires that no errors are allowed in transmission and packets are retransmitted otherwise. This characteristic is inherent feature of Bluetooth where packets are sent repeatedly by the transmitter until it receives an acknowledgement back from the receiver indicating that the packet was received correctly. In future directions of our project involving the support of more data packet types such as DH1, DM3, DH3, DM5 and DH5, this feature will need to be disabled such that an estimate can be made about bit error rates in transmitting JPEG images via Bluetooth. Essentially, without any type of Forward Error Correction (FEC) or cyclic redundancy checking, the packet would be an AUX packet type, transmitted as best effort UDP. This would increase throughput given that we no longer have to use bytes for the CRC code. Also, this would decrease idle time in the master since it would no longer have to wait for an acknowledgement packet sent by the slave device before sending another data packet.

Data reception: The receiver is always waiting for a new packet. When a new packet is detected, it must register it and enable the decoder. Currently, the majority of the receiver code involves checks to ensure the correct

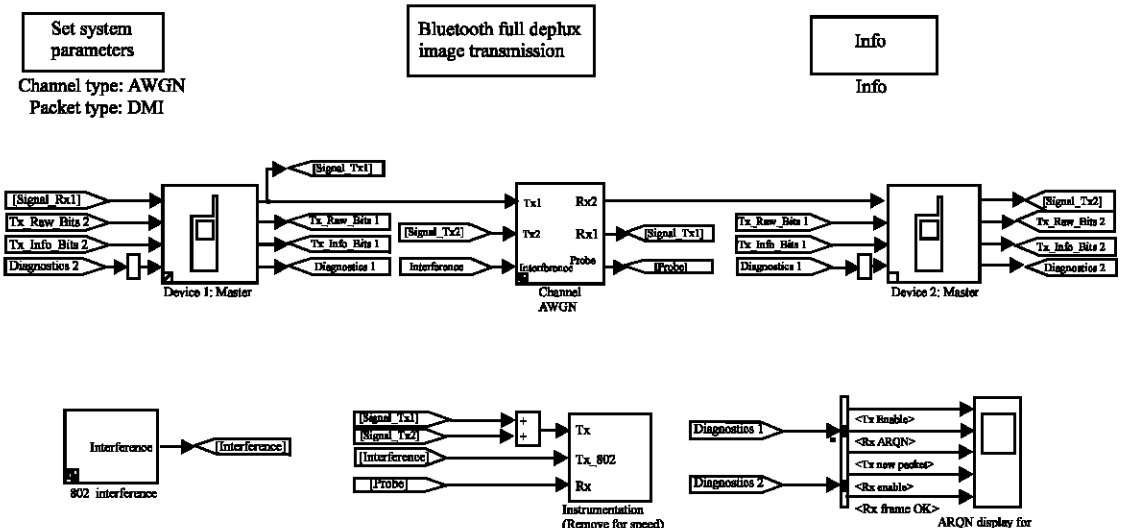

Fig. 8: Simulink model of bluetooth transmission

detection of a packet. Future changes in this design to incorporate JPEG image transmission will no longer need this feature as BER will be the parameter of interest.

Frequency hop generation: The Bluetooth wireless specification defines a technology that operates in the unlicensed 2.4 GHz radio spectrum. It uses a spread spectrum, frequency hopping, full-duplex signal up to 1600 hops sec^{-1}. The signal hops among 79 frequencies at 1 MHz intervals to give a high degree of interference immunity.

In the simulink model, there exists a frequency hop generation block that emits a new frequency every cycle for the data to use for transmission. Some study has been done already to support different data packet types that need to be transmitted over the same frequency over multiple clock cycles (e.g., DM3, DH3, DM5, DH5), but further refinements are needed.

RESULTS AND DISCUSSION

One of the most difficult problems we encountered in our implementation involved modifying the Simulink model to support file I/O. As given, the model modeled the bits in an image and just a random series of integers generated from a random number generator. We needed to have the code actually read in binary information from a image file that had been compressed using JPEG. Similarly, we needed a way to output the received image to a file so that we could subsequently examine the effect of JPEG image transmitted using Bluetooth.

ECG data which is to be sent to the base station is in the form of image. The ECG image is taken and the image is decomposed into matrix by using imread () function. The image is 256*256 and hence after the decomposition of the matrix into pixels, the dimensions of the matrix will be the same as its size. The data fed to the 'Integer to bit conversion' block should be in vector form. The matrix is converted to vector form by using reshapm () function. Appropriate payload header is multiplexed along with the payload. CRC block enables error check to be performed on the data being transmitted.

The payload bits then moves to the AWGN channel block where the actual simulation of Bluetooth channel occurs. In this block, the characteristics of the Bluetooth channel such as frequency of transmission are set. The output from the AWGN channel block is given to the Rx input of the slave block. The bits are then arranged into data of 8 bit format. Payload header is then separated from the data received. BER should be zero other wise the ARQ requests to resend the bit being transmitted. Image is reconstructed and the received matrix which is in vector from is converted to 256*256 matrix by using the reshape function. The reshaped matrix is put into image format using imwrite() fuction available in Matlab. All the images are of uint8 datatype which has to be taken care of before using imwrite function otherwise the image would be blurred.

Figure 9 shows the transmitted and received ECG signal. The faithful reproduction of received data is verified by finding variance of the transmitted and received images and then taking the log of the variance of

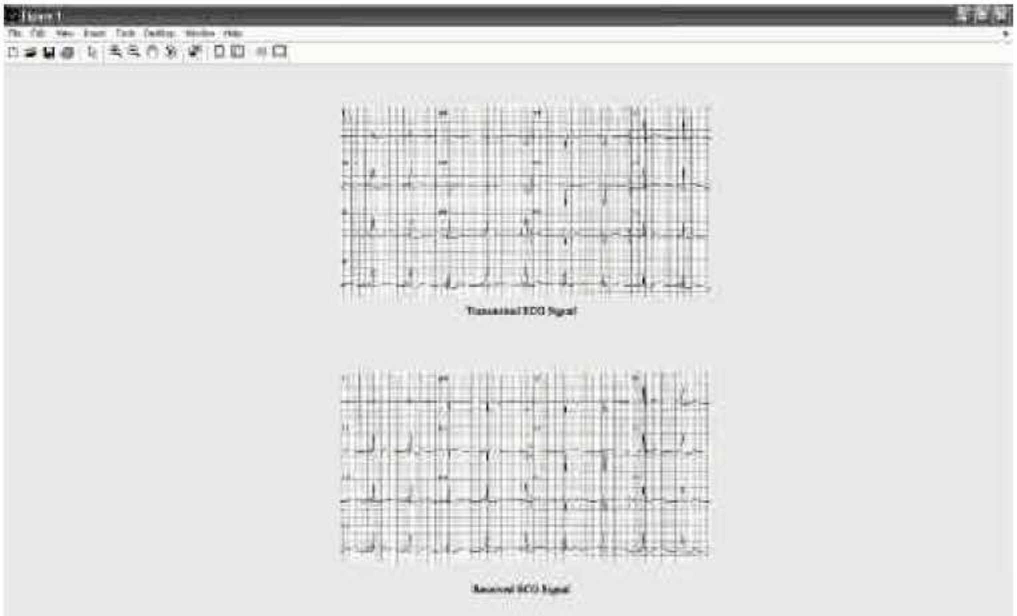

Fig. 9: Transmitted and received ECG

the transmitted image (matrix) to the variance of the received image(matrix).

CONCLUSIONS

The ratio of variance of the transmitted and received images is calculated and found to be unity. This shows that transmitting the medical parameters using Bluetooth will not contribute to the error rate as to that of its counterpart. In addition, the BER of the data is zero but increases over the time. This disadvantage is overcome by means of ARQ hard wired in the Bluetooth functionality. Hence the information transmitted would reach the destination with minimal error which also can be corrected.

In the future this handheld device can be enhanced as homecare system, so that handheld device would log on the patient's vital parameters to the hospital server from the web server through Internet.

REFERENCES

ARM920T Processor, Atmel Reference Guide.

Bauer, P., M. Sichitiu, R. Istepanian and K. Premaratne, 2000. The mobile patient: Wireless distributed sensor networks for patient monitoring and care. In Proceedings of IEEE EMBS International Conference on Information Technology Applications in Biomedicine, Arlington, pp: 17-21.

Bieliková, M., 2002. A body-monitoring system with EEG and EOG sensors. In ERCIM News No. 51.

Dandamudi, S.P., 2005. Guide to RISC Processors: For Programmers and Engineers, 1st Edn., Springer.

Furber, S., 2000. ARM System on Chip Architecture, 2nd Edn., Addison-Wesley.

http://www.arm.com/

http://www.arm.linux.org.uk/

http://www.bluetooth.com/

http://www.bluez.com/

http://www.mathworks.com/

John, H.W., (Ed.) 1991. Operating room and intensive care alarms and information transfer. Symposium Paper held at Zurich, Switzerland, 27th Feb 1991.

Nathan, S.M., 2001. Bluetooth Demystified. Tata McrawHill, India.

Paul, N., M.D. Lanken, C. WilliamIII, M.D. Hanson and S. Manaker, 2000. The Intensive Care Unit Manual. W.B. Saunders Company.

Rusch, T.L., R. Sankarand and J.E. Shcarf, 1996. Signal processing methods for pulse oximetry In computers in biology and medicine. Elsevier Sci., 26: 143-159.

Varshney, U., 2006. Transmission of emergency messages in wireless patient monitoring: Routing and performance evaluation. In Proceedings of the 39th Hawaii International Conference on System Sciences-2006.