DESIGN AND IMPLEMENTATION OF HUMAN DIGITAL MODEL FOR TRANSPLANTED ORGAN MONITORING USING ARTIFICIAL INTELLIGENECE (AI)

Dr.M.UMADEVI , Dr. P.PONNUSAMY

Abstract: In this paper, an investigation and design of involving the liver implanted wireless telemetry link using UWB technology is presented. Measurements using multilayer phantoms and simulations using a human digital model have been conducted within the frequency band of 60GHz. Multilayer phantom measurements have demonstrated the attenuations ranging between –50 and –100 dB over the considered frequency band. A path loss model at the liver area has been obtained from the simulations. Also, the numerical results have shown that the attenuation variation due to respiration-induced organ movements was within 30-dB range with respect to the largest organ movement distance of 40 mm, which emphasized the influence of organ movements on the in-body attenuations. A model for improving battery life is done by sensing the organ movement using AI method (BPN). Puncturing process is done based on organ movement. Frequency is improved to 60 GHz instead of 3-6GHz. Data encoding done based on DNA sequence.

Key words: Computer Simulation Technology (CST), Antennas, Body area network, Ultra wide band (UWB), Implantable biomedical device.

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1. INTRODUCTION

Recently, wireless implanted devices for sensing and monitoring body parameters have been viewed as an attractive solution to facilitate the need for improving healthcare systems [1], [2]. These devices can monitor process and transmit physiological data of a person to the healthcare service providers and hospitals, leading to improved medical diagnoses and treatments. One promising application of wireless implanted devices is the physiological monitoring of transplanted organs. In the present age, organ transplantation is being performed more often than before during medical treatments [3]. Particularly, with the advancements in medical science over the past few decades, liver transplantation has been recognized universally as the standard medical treatment for end-stage liver diseases,acute fulminant hepatic failure, hepatocellular carcinoma and hilar cholangiocarcinoma [4], [5]. However, at an early stage, transplantation failure is reportedly highest during the first two week period immediately after surgery [6]. Conventional procedures for post-transplantation monitoring such as daily blood testing and tissue biopsy are invasive and have a slow response to the potential failure of transplantation. Being one of the most common solid organ transplantations across the globe and the limited availability of donated organs, it is extremely important that the failure rate of liver transplantation is minimal.

Implanted wireless monitoring of a transplanted organ can provide a practical solution for timely detection and intervention before critical damage occurs, which will eventually help in reducing graft loss and mortality [6]. Fig. 1 illustrates an overview of the wireless implanted monitoring system for an example case scenario. The wireless implanted device is placed on the surface of the transplanted liver, transmitting physiological data such as hepatic perfusion and oxygenation levels which are the risk indicators of a transplanted liver to the on-body node. This on-body device then acts as a transmission hub and wirelessly relays the data to personal devices of the patients, doctors and servers in a hospital.

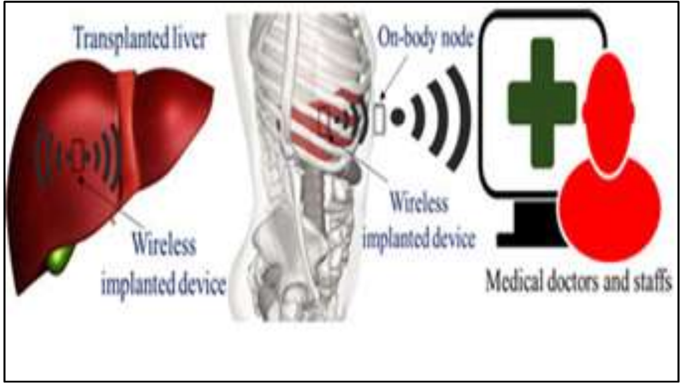

Fig 1 *Overview of implanted device communication*

This wireless monitoring application can offer a reliable mean to constantly report the real-time physiological status of a patient to a healthcare-monitoring personnel. Additionally, this application would shorten the length of hospital stay, leading to a reduction of recovering periods and medical costs. Ultra-wideband (UWB) technology is a potential candidate for wireless implanted applications [7]–[9]. Its high frequency level enables substantial reduction in the physical size of the implanted antenna and thanks to

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- *Dr. M. Umadevi Associate professor Department of ECE Priyadarshini Engineering College, Vaniyambadi-635751 Email : uma_san2001@yahoo.co.in*
- *Co-Author Name: Dr.P.Ponnusamy Associate professor School of Mechanical Engineering Vellore Institute of Technology -632014 Email : sreepons@gmail.com*

the simplicity of the transmitter side, these advantages can contribute to the miniaturization of implanted devices. The low power consumption potential of UWB will also lead to the increase of device longevity. Furthermore, UWB offers high data rate transmissions which would facilitate various innovative applications such as implantable drug delivery and micro robots for in-body biopsy and treatment procedures [11]. Moreover, with the potential use of biodegradable materials in the future, an implanted device will not require a removal, thus leading to a reduction of risks to the patient. However, UWB signals attenuate quickly when propagating inside the human body. This leads to performance degradation and makes the realization of in-body wireless communication difficult. Therefore, a thorough understanding of the propagation characteristics at UWB frequency is necessary in order to ensure reliable wireless communication links inside the human body.Since it is not practical to conduct research on in-body wireless communication on a real human and human individuality can lead to variations of measurement results [12], [13]. We use human body phantom in experiments and numerical model in simulations in our studies.Propagation channel for in-body scenario highly depends on the implantation location since different channel links involving different organs and tissues cause variations in channel characteristics. In-body propagation channel at UWB range for different locations are reported in the open literatures,e.g,chest,brain,torso,and embedded in muscle [18]. Nevertheless, to the best of the authors' knowledge, there is no existing study available in any open literature for the liver-toskin UWB propagation channel. Therefore, to investigate the characteristics and performances of liver implanted wireless communications using UWB channel, we performed simulations and measurements using simplified multilayer phantoms [19] and numerical investigations using realistic human phantom considering the effect of respiration-induced organ movements on signal attenuations [20]. In this work, firstly, simulations and experimental measurements using simplified multilayer phantoms are performed to obtain S-parameter results, followed by the comparison and discussion of the experimental and numerical results. With respect to [19], the return loss result of the on-body antenna in the measurement was improved and better agreements between simulated and measured transmission coefficient results can be observed here. Consequently, we continue our study on propagation characteristics of UWB channel at liver location in more realistic scenario by conducting simulations using realistic human voxel model. While the study in [20] was conducted with only vertical orientation of the in- and on-body antennas, both horizontal and vertical orientation of the antennas are considered in this paper. With respect to [20], the impedance matching characteristic on the on-body antenna was improved. Furthermore, we investigated the influence of upper abdominal organ movements due to respiration on the attenuation level up to 40 mm in the craniocaudal axis compared to 20 mm in [20]. Consequently, our new findings on path loss and link budget for system performance evaluation are later studied and discussed. Our results highlight the significant variations of attenuation within the range of 30 dB due to the movements of upper abdominal organs up to 40 mm during normal respirations. Quantitative data of path loss and the system performance of liver implanted wireless communication channel at UWB range are presented. Results suggest that high data rate as 10Mbps can be achieved. These results would facilitate the design of the efficient and reliable wireless telemetry system and can be applied to other wireless implanted applications using UWB technology at liver location.

2. DESIGN AND METHODOLOGY

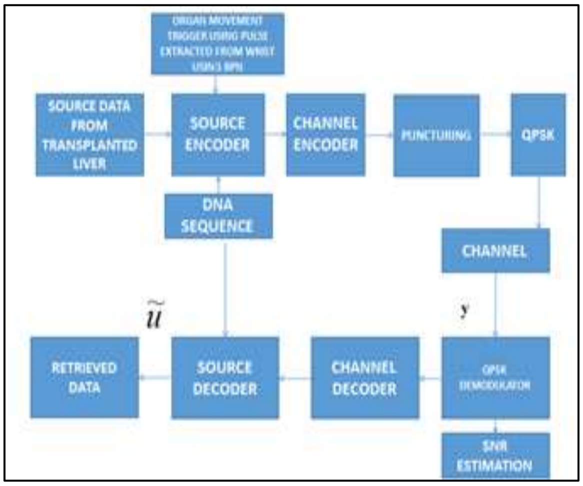


Fig.2 *Block diagram of proposed method*

2.1 S parameter

The return loss results of the on-body and in-body antennas within the frequency range of 4.5–6.5 GHz are presented in Fig. It can be noticed that both antennas have shown good performance. The variation of S21 results along the vertical axis indicates the effect of organ movement on the signal attenuation inside the human body. In the results, the maximum variation range of attenuation is around 30 dB and the largest deviation of attenuation from mean attenuation at each horizontal distance is around 15 dB. These results highlight the important insights about the impact of organ movements on the signal attenuation.

2.2 Path Loss Model

The simulated S21 data was processed to obtain the path loss (PL) data of each link as PL = – {| S21 |} in decibels. Subsequently, the path loss of the in-body channel was modeled by applying linear fitting algorithm to the path loss data as shown in Fig. and the path loss parameters of (1) was obtained for the reference depth of implantation, d0 = 31.54 mm. Thus, the parameters of the fitting PL model are as follows, PL0 = 51.31 dB and n = 6.06.

$$\mathrm{PL_{dB}}\,(\mathrm{d}) = \mathrm{PL_{0,dB}} + 10n\log_{10} \cdot \left(\frac{\mathrm{d}}{\mathrm{d0}}\right) + \mathrm{S_{dB}}.$$

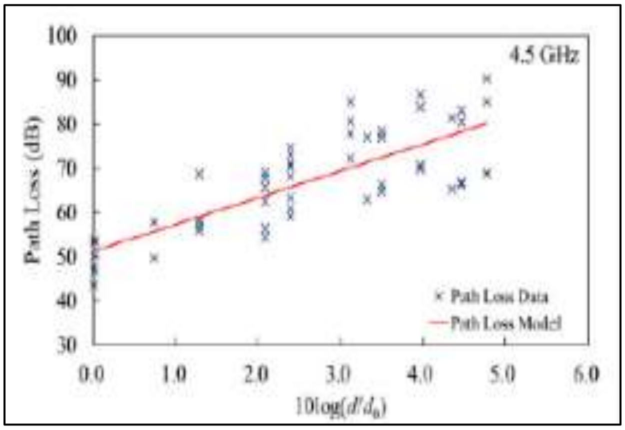


Fig 2.2.1 *Linear fitting of path loss model*

For the first time, the propagation characteristics of in-body communication channels using UWB technology by means of both measurement and simulation results for liver implanted wireless telemetry link. It serves as an important preliminary study for wireless liver implanted applications. Frequency-dependent attenuation results obtained from the phantom measurements were presented and discussed. It should be mentioned that multilayer phantoms without skin layer may lead to an underestimation of the attenuation results, however, using simplified multilayer phantoms can offer acceptable approximation of the channel characteristics. The numerical results demonstrate the attenuation variations affected by respiration-induced organ movements. The path loss model at liver location was derived from the simulations. The preliminary assessment of the system performance taking into account the effect of shadowing and organ movements indicated that it is viable to implement the liver implanted wireless system using UWB channel and achieve a high data rate transmission. The quantitative information presented in this paper can be used in the designing of liver implanted wireless communication system. This study could also offer a guideline for further analysis of various in-body wireless medical applications using UWB technology.

In addition, it is clear that this work attempted to imitate human breathing scenario to approximate the effect of human respiration on the channel characteristics, hence, our future work will aim to improve the accuracy of the channel characteristics by conducting simulations using dynamic breathing human model. Moreover, since different humans vary in terms of body size and mass, simulations using various numerical human body models will be conducted in our subsequent investigations of in-body channel characteristics

2.3 SIMULATION WAVEFORM:

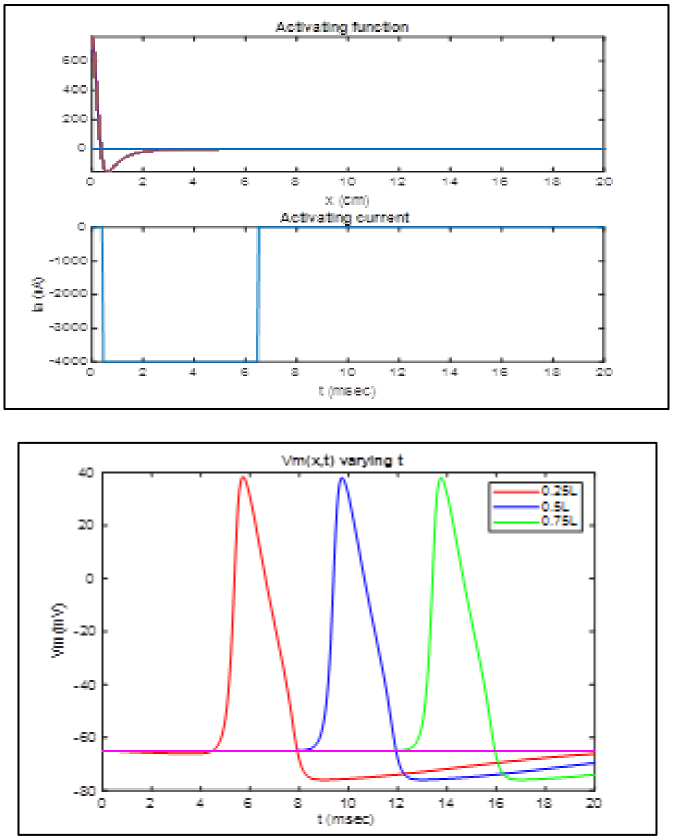
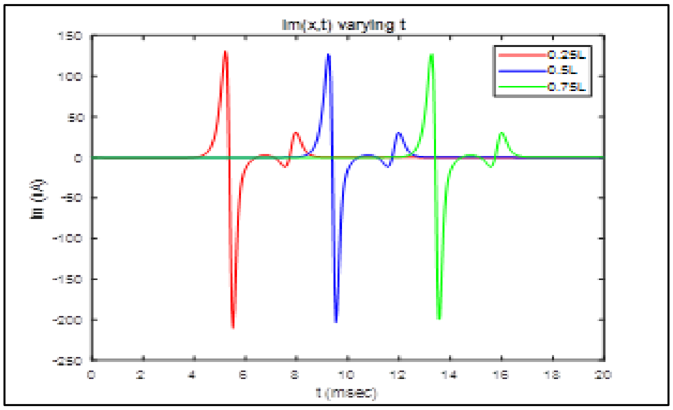


FIG.2.3.1 *(a) Activation Function*



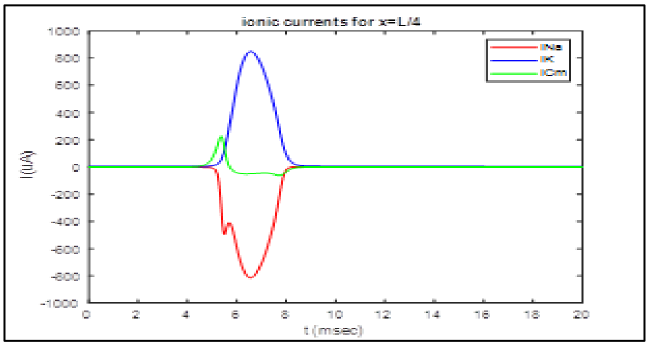


***FIG 2.3.2(b)** shows the individual current magnitudes which is contributed by 3 different ionic materials. The graph is shown when the distance of current travel is kept constant*

3.BACK PROPAGATION ALGORITHM

BPNN is a supervised algorithm in which error difference between the desired output and calculated output is back propagated. The procedure is repeated during learning to minimize the error by adjusting the weights through the back propagation of error. As a result of weight adjustments, hidden units set their weights to represent important features of the task domain. BPNN consists of three layers: 1) Input Layer 2) Hidden Layer and 3) Output Layer. Number of the hidden layers, and number of hidden units in each hidden layers depend upon the complexity of the problem. Learning in BPNN is a two step processes.

Step 1 (Forward Propagation): In this step, depending upon the inputs and current weights, outputs are calculated. For such calculation, each hidden unit and output unit calculates net excitation which depends on:

- Values of previous layer units that are connected to the unit in consideration.
- Weights between the previous layer unit and unit in consideration.
- Threshold value on the unit in consideration.

Step 2 (Backward Propagation of Error): During this step, error is calculated by difference between the targeted output and actual output of each output unit. This error is back propagated to the previous layer that is hidden layer. For each unit in the hidden layer N, error at that node is calculated. In the similar way, error at each node of previous hidden layer that is N-1 is calculated. These calculated errors are used to correct the weighs so that the error at each output unit is minimized. Forward and backward steps are repeated until the error is minimized up to the expected level.The aforementioned figure is that the window output of the matlab program, when we generated an ECG

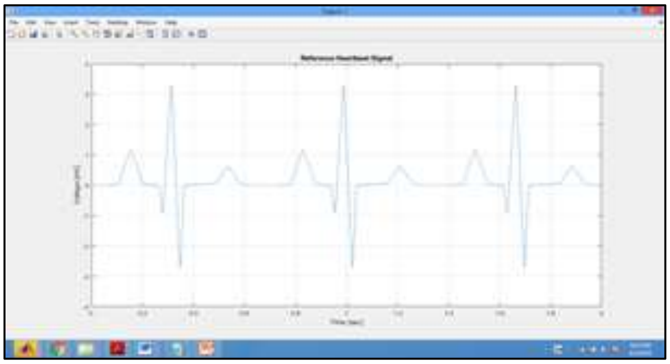


***Fig.3**.Neural Network Classification of Peak Detection in ECG*

Signal through the built in command of matlab window took from statistical and mathematical tool box. The waves are synthetically generated and the time duration of ECG signals generated are exactly for 2 seconds. Actually there are 40 ECG signals in the above figure. But, for the sake of visual clarity on the signals, only 3 cycles of ECG have been shown. The highest amplitude of the signal to be 3.2mV which consists of P,Q,R,ST,U,V waves as seen in the standard benchmark test ECG.

4. RESULTS

SIMULINK MODEL

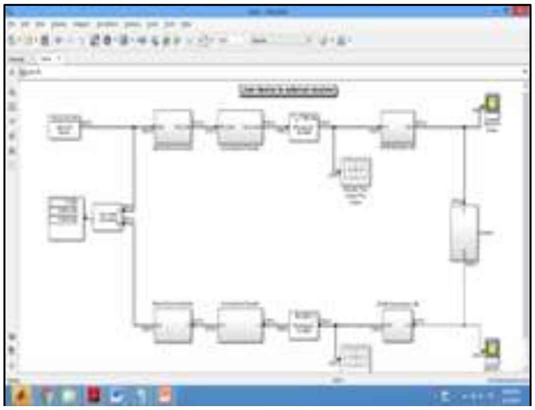


***FIG.4**.Simulink model is a graphical programming environment for modeling, simulating and analyzing digital human model of dynamical systems.*

It is used for BER calculation of liver device to external receiver when AI is not implemented

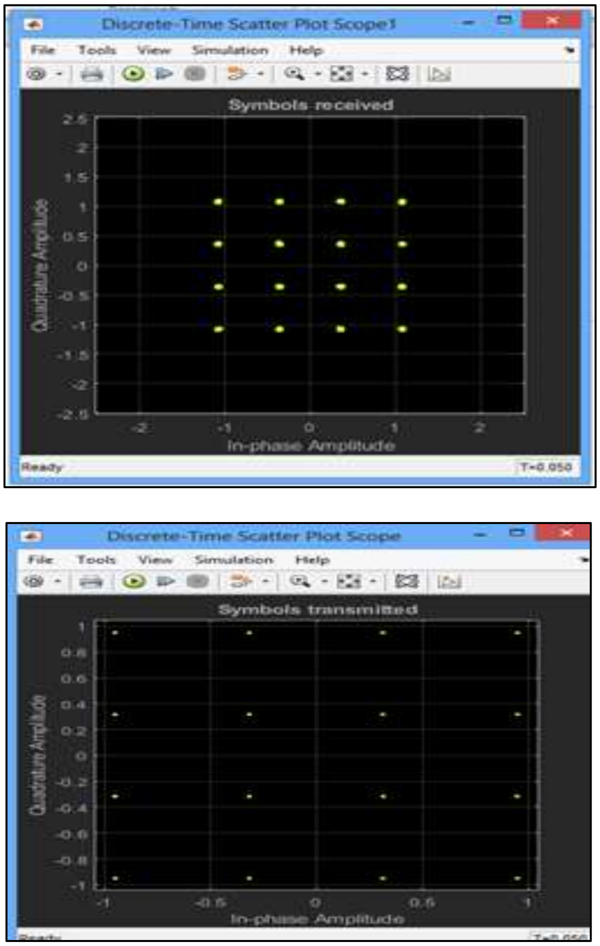


***Fig. 4(a)** Transmitted Constellation and Received constellation Without AI Implementation*

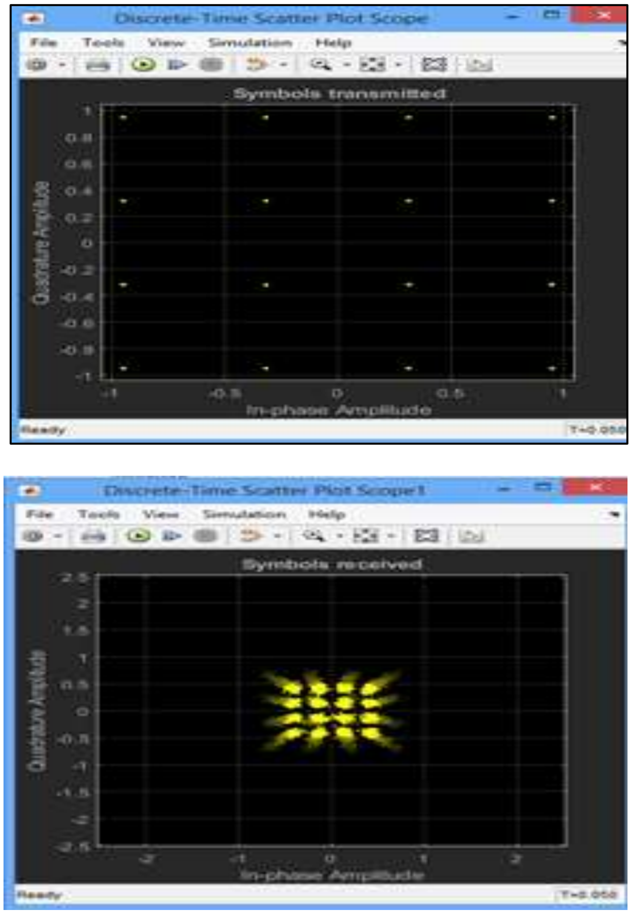


Fig.4 (b) *Transmitted and Received Constellation with AI Implementation*

5. CONCLUSION

A simulation of wireless communication needs its equivalent electrical circuits and various chemical dynamics involved in it. A GUI design has to be made using MATLAB 2018 software, in order to simulate the bacterial movement striving for food. The radial distribution of electromagnetic power inside the muscles has been plotted. This simulation is needed just to find the possible end node in the out of vicinity of communication. In this tenure of work, we have implemented a muscular model along with a communication model under BPN and without BPN. With this work keeping as a base, we would extend this to a gated logic, of the communication system setup along with the path loss model and shadowing model under QPSK modulation. Further, in further experimental works, we have arrived at a conclusion that the proposed AI method outperforms in the least values of BER. This acceptable BER is obtained helps us to reduce the number of re-transmission and helps to reduce the power consumption at the transmitted implanted in the inner body. Ultimately it enhances to extend the battery life. Hopefully, the Lithium battery kept inside the body is expected to have life span of around 20 years instead of 10 years of the existing battery life.

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