Analysis and Simulation of Propagation Model for Wireless Communication of Bio-Sensors

Shama Siddiqui
Department of Computer Science
Iqra University,
Karachi , Pakistan
shamasid@hotmail.com

Vali Uddin Abbas
Department of Electrical Engineering
PNEC, NUST
Karachi, Pakistan
v_uddin@hotmail.com

Mustafa Asghar Ali
Department of Computer Science
Iqra University,
Karachi, Pakistan
mustafa.asgarali@hotmail.com

Abstract— **It has become possible to implant a network of Bio sensor nodes inside human body for remote health monitoring, diagnostic and prosthetic purposes. For communication of these sensors the channel available is human tissue. The sensors communicate using wireless technology, by sending information as electromagnetic (EM) radio frequency (RF) waves. These signals encounter a significant loss during transmission because this communication channel contains a major portion of fluid. To find out this loss, a propagation loss model PMBA has already been developed. This paper investigates the appropriate distance between nodes for better communication. The frequency range of Radio spectrum (1GHz to 3.5GHz) is used for MATLAB simulation. It is observed that as frequency of transmitting signal is increased, the distance limit is decreased and Power loss is increased. Using radiation pattern it is shown that the electric field intensity decreases with increasing distance.**

Keywords-component; Bio-sensors; implantation; dielectric properties; dipole; electric field intensity.

I. INTRODUCTION

Implanted network of Bio sensors inside human body is of great interest because it provides remote health monitoring facility, which is significant in terms of prevention. A Bio Sensor is a device that can detect, and transmit information about any change produced in a living system. The system may consists of various bio-sensor nodes implanted at different locations inside human body e.g. for monitoring of blood pressure, EGC, pulse, blood glucose level etc. These sensors communicate with external base station as well as with each other. This paper deals with the main issues of the intra body communication which may be required for various applications such as retina prosthesis for visually impaired persons [1]. Wired communication within the body is not practical to implement, because it becomes a hazardous and time consuming task. Hence wireless technology is used. This communication of Bio sensors within human body is a great research issue because the channel available for this communication is not free space, but it is human tissue, which is considered as a lossy medium due to presence of lots of fluid. Hence a significant loss in transmitted power from implanted node takes place before it can reach the other (receiver) node, which is mainly because of the absorption of power in the tissue channel [2]. Due to presence of this channel the model becomes essentially different from traditional wireless networks in which free space is used as a communication channel. Therefore, the models which have been developed for free space communication need to be modified by taking Dielectric properties of human body into account [3,4].

Calculation of Specific Absorption Rate (SAR) is significant to find out the power absorbed by human tissue. This absorption is directly proportional to the frequency, which results in tissue warming, due to which tissue damaging may occur. In order to avoid this, lower frequency range must be used, but if frequency is lowered, the wavelength will increase, due to which the dimensions of antenna will have to be increased as antenna dimensions are directly related to wavelength [6]. Hence there is a trade-off between frequency and antenna dimensions. For implantation purposes, high frequency RF waves are used, which makes the size of antenna practical for implantation.

As power loss in RF signal varies inversely with the distance, therefore it becomes important to calculate the maximum distance between nodes inside the body, so that they can communicate in efficient manner.

II. RELATED WORK

There has been a considerable research done in energy harvesting techniques in order to provide power to implanted bio sensors, as they must have small but continuous power. Different harvesting technologies for self-powered bio-sensors, including conversion of nano scale mechanical energy into electrical energy and use of hybrid cell for solar and mechanical energies are discussed in [5].

Implanted network of Bio Sensors can provide expanded health care services for persons who require continuous monitoring. These networks require a technological platform as well as algorithms which must be time sensitive and must avoid packet collisions in wireless environments. The use of implicit Earliest Deadline First policy is recommended in [8] to reduce congestion in network traffic flow.

As these networks are fundamentally different from those working in free space, so energy utilization must be accomplished in an efficient manner; So that, the network works on minimum possible energy. Two different energy efficient communication protocols, namely cluster-based and tree-based protocols are compared and analyzed that are designed to reduce energy consumption [7]. The analysis shows that the cluster-based protocol has better energy performance.

Propagation of EM wave in a medium mainly depends on its dielectric properties. The dielectric properties of body tissue have been investigated in [3] to determine pathway of current flow inside the human body. The propagation loss model for intra body communication of Bio sensors network has been developed in [2]. However the appropriate distance between sensors for effective communication has not been discussed. In this paper, the goal of our research is to find out this distance, and variation of electric field intensity with respect to distance.

III. SYSTEM MODEL

For simplicity, this paper considers only two implanted bio sensor nodes connected with elementary oscillating (Hertzian Dipole) antenna used for transmission and reception of RF waves. The length of the dipole is the main determining factor of the operating frequency of the antenna.

One reason for using dipole antenna is the fact that even though the Hertzian short dipole is very small in size, its effective aperture is comparable to antennas which are many times larger than it [4].

One way to overcome the body losses during implanted communication is to make an efficient transmitting antenna. Due to practical constraints, antenna should be of very small size, i.e. in order of a few millimeters, which is another reason for using small dipole antenna for this model.

A very small portion of tissue surrounding antenna is considered so that tissue can be considered as homogeneous medium, so that it can be considered that power loss is not due to scattering or diffraction, but it is mainly due to absorption by tissue.

As the channel for this communication model is human tissue, therefore dielectric properties of human tissue i-e conductivity, permittivity and permeability must be considered [4].

The channel around the transmitting antenna is bifurcated in near-field and far-field regions, because the power loss in the near field depends mainly on H-field and in the far field, it mainly depends on E-field.

In general, it is considered that far field starts from the distance which is larger than the wavelength used. In this field, both components of the electromagnetic field become perpendicular to the direction of wave propagation.

Therefore, power loss is calculated by using different equations which are derived using Maxwell equations of E and H-field inside a lossy medium [1]. The extent of near field, for short dipole it is given by $d_o = \lambda / 2\pi$.

IV. MATHEMATICAL MODEL

Equations for Power received for dipole antenna in near field is given as follows [2]:

$$P_R = \frac{16\delta(P_T - P_{NF})}{\pi L^2} A_e \tag{1}$$

Where P_T: Power Transmitted, P_{NF}: Power lost in near field, L: Largest dimension of antenna, A_e: Effective aperture of antenna, δ: Aperture efficiency, and it is given by $\delta = A_e / A$, typical value ranges between 0.5 and 0.75.

For far field, Power received is given as:

$$P_R = \frac{(P_T - P_{NF} - P_{FF})\lambda^2}{(4\pi d)^2} G_t G_r \tag{2}$$

Where, P_{FF}: Power lost in far field, G_t & G_r are antenna gains of transmitter and receiver antennas respectively, d: diameter of receiver antenna.

Equations for Power lost in near and far fields are derived in [1]:

$$P_{NF} = \sigma\mu\omega \frac{|\eta|}{|\gamma|} \frac{I^2 dl^2}{6\pi} \left[A + B + C \right] \tag{3}$$

A, B & C are integration constants.

Electric field intensity in terms of angle θ is given as [7]:

$$E_\theta = \eta \frac{Idl \sin\theta}{4\pi} e^{-\gamma R} \left(\frac{1}{\gamma R^3} + \frac{1}{R^2} + \frac{\gamma}{R} \right) \tag{4}$$

V. SIMULATION MODELING AND RESULTS

For simplicity in simulation of model, only two sensor nodes are considered.

Length of the dipole is calculated by the formula [9]:

Length (meters) = 150 x A / frequency in MHz

where A: ratio of the length of the antenna to the thickness of the wire used, typical value ranges from 0.96-0.98

Since frequency range of interest is 1GHz to 3.5GHz, therefore the suitable length of nodes is found to be 25mm which is much smaller than wavelength according to requirement of Hertzian Dipole, and diameter of antenna is considered to be 1mm [1].

A. Distance Limit for Near Field

Simulations are performed for finding the distance limit of near field at various frequencies, as it is practical to find out the appropriate distance for effective communication, before actually implanting the nodes inside the body. It is observed in Figure 1 that extent of near field contracts at high frequencies.

Figure 2 analyses the near field limits for entire frequency range, by assuming receiver antenna to be placed at different points surrounding the tissue channel. It can be seen that, near field region is widest in the case of minimum frequency, i.e. 1GHz. Its value is about 4.8cm. But as frequency is increased in step of 0.5GHz till 3.5GHz, near field region is found to become narrower, such that its value reduces to only 1.5cm at 3.5 GHz. It is also observed that value of power received is much higher for low frequencies as compared to higher ones. At 1GHz, value of power received is found to be approximately 5 µW, which reduces to 0.5 µW at 3.5 GHz.

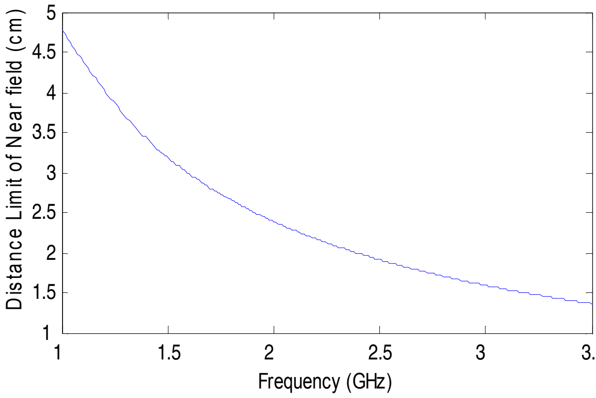

Figure 1. Distance limit for near field with respect to frequency

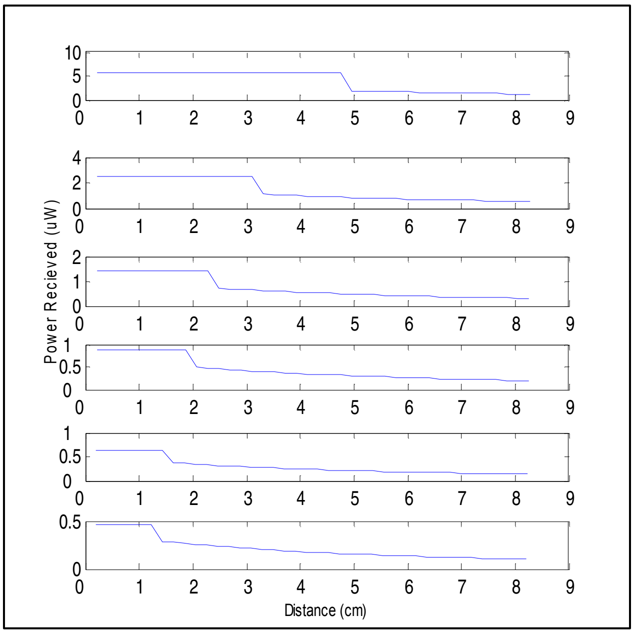

Figure 2. Relation between received power and distance for various frequencies (a) 1GHz (b) 1.5GHz (c) 2GHz (d) 2.5GHZ (e) 3GHz

B. Power Loss.

Power loss for intra body communication is simulated by using Propagation Loss Model for Wireless Bio-Medical Applications [1]. Loss is plotted against frequency range of 1GHz to 3.5 GHz. Distance limit is considered both for near field and far field regions. It is shown in figure 4 that, for near field, computed loss increases consistently from about -12dB (at 1GHz) to about -38dB (at 3.5GHz).While, loss increases from approximately -62dB (at 1GHz) to -85dB (at 3.5GHz) for far field.

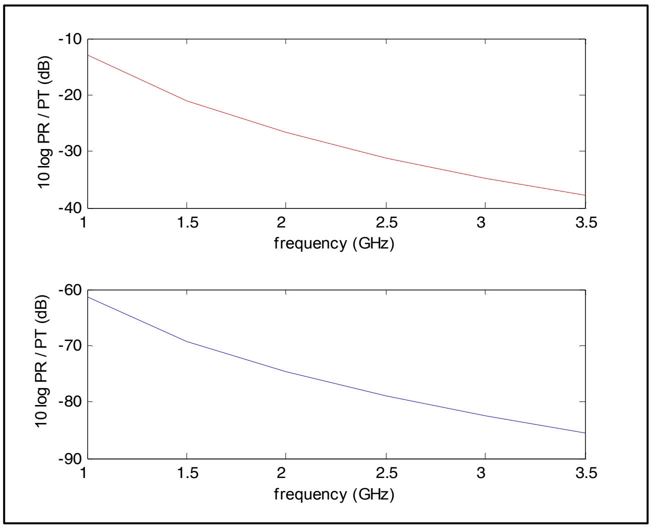

Figure 3. Power Loss in (a) near field (b) far field.

C. Radiation Pattern of Half Wave Dipole inside Human Body

The angular variation of the electric field E_θ is known as the radiation pattern of the antenna. Radiation pattern of short Dipole is plotted using MATLAB.

The radiation patterns are plotted by considering transmission of single frequency wave, i.e. 2.5 GHz, while changing the distance from transmitter node. As it is shown in figure 1 that near field limit for this frequency is approximately 1.9cm, so pattern is plotted for near field as well as distances beyond this limit.

The results in Fig.4 & Fig.5 show that electric field intensity decreases on increasing the distance, which is same as the case with power received.

As distance becomes 1.5 cm, intensity is found to be 0.08 V/cm which gets maximum at the direction of 90^o, and falls to zero along the axis of antenna as shown in Fig. 4(a). Fig. 4(b) shows the pattern when distance is just equal to the boundary of near field, at this point field intensity obtained is approximately 0.05 V/cm.

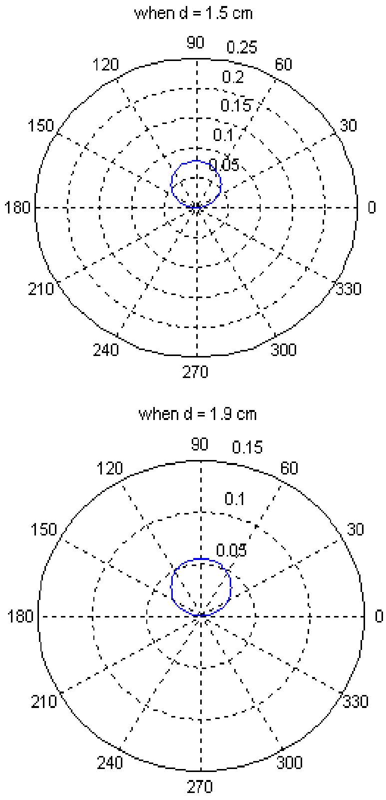

Figure 4. Radiation pattern within near field for f=2.5GHz when (a) d= 1cm, (b) d= 1.9cm

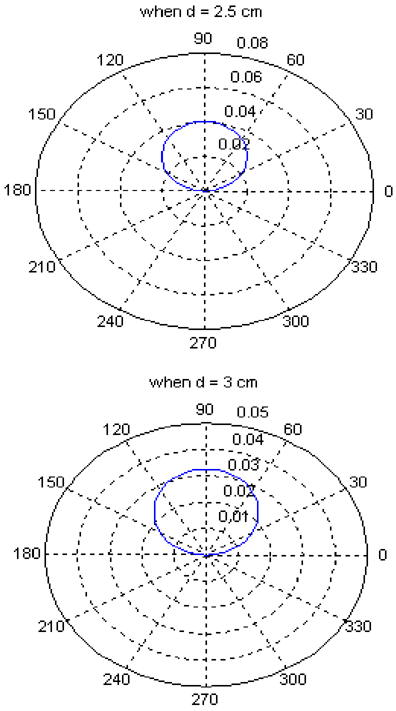

Figure 5. Radiation Pattern for Far Field for f = 2.5GHz

CONCLUSION

The distance limit for near field and power received is proved to be decreasing for high frequencies. So for better communication, it is recommended that antenna should be placed within the specific near field distance limit for the intended frequency. Radiation pattern shows that electric field intensity decreases rapidly beyond near field limits.

FUTURE WORK

As it is stated that high frequencies are hazardous for health, but there is a trade-off between antenna size and frequency, so antennas should be design which can work well for low frequencies for the purpose of implanted communication. Loop and patch antennas are far better choices. Therefore, we plan to develop the same model for different antenna types. Further advancement in this research can be made by assuming large portion of human tissue channel without taking homogeneity into account.

REFERENCES

[1] Schwiebert L., Gupta S.K.S., Auner P.S.G., Abrams G., Lezzi R., McAllister P., "A Bio-Medical Smart Sensor for Visually Impaired", Sensors 2002, Proceedings of IEEE, Vol 1 p.693-698

[2] S.K.S Gupta, S. Lalwani, Y.Prakash, E.Elsharawy, L. Schwiebert, "Towards Propagation model for Wireless Bio Medical Applications", IEEE Conference on Communications, 2003 p.1993-1997

[3] Marc Simon Wegmueller, Micheal Oberle, Niels Kuster, Wolfgang Fitchner, "From Dielectrical Properties of Human Tissue to Intra-Body Communication", World Congress on Medical Physics and Bio Medical Engineering, 2006.

[4] An internet resource for the calculation of Dielectric properties of body tissues. http://niremf.ifac.cnr.it/tissprop/

[5] Zhong Lim Wang, "Top Emerging Technologies for self-Powered nano systems; nanogenerators and nanopiezotronics", Chinese Bulletin, Vol. 54 Number 22, November 2009

[6] T.S. Rappaport, "Wireless Communications Principles and Practice", Prentice Hall, 1996.

[7] Shankar, V. Natarajan, A.Gupta, S.K.S Gupta, L. Schwiebert, "Energy-efficient Protocols for Wireless Communication of Bio-Sensors Nettworks", Personal, Indoor and Mobile Radio Communications, 2001 12th IEEE International Symposium, 2001.

[8] Raul Aquino-Santos, Apolinar Gonzalez Potes, Victor Ranel-Licea, "Wireless Communication Protocol Based on EDF for Wireless Body Sensor Networks", JART, Vol. 6 No.2 August 2008

[9] http://www.radio-electronics.com/info/antennas/dipole/dipole.php