Simulative Investigations of Wireless Body Area Network through Varied Channel Conditions

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ABSTRACT
In this paper, the power profile for WBAN channel have been generated by using Rayleigh and Weibull distributions. [1]The value of mean path loss has been calculated and compared for different values of carrier frequency , relative body movement and number of scatterers. Moreover, the channel gain profiles have been plotted to obtain mean fading values for the optimum values of carrier frequency, relative body movement velocity and scattering density. Through extensive simulations, those values have been identified which shows minimum fading.

General Terms
WBAN channel model , IEEE 802.15.6

Keywords
Wireless Body Area Network ,Fading Power profile, Fading, Path loss, Shadowing.

1. INTRODUCTION
Wireless communications will be one of the key components for the information society. Wireless body area network (WBAN) is a promising technology which includes a wireless network usually formed by lightweight, small-size, ultra-low-power and intelligent sensors which are placed in(implantable) and around(wearable or placed close to) the body. These sensors measure, process, and transmit the body's physiological signs to a control unit (CU) without constraining the activities of the wearer. Doctors and caregivers can then access the collected data for real-time diagnosis and trigger treatment procedures in return. This gives patients greater mobility and increased comfort by freeing them from the need to be connected to hospital equipments that are required to monitor their conditions [9]. This also prevents patient from any kind of sudden attack.

Body area networks also have implications beyond the medical setting. WBANs could play a huge role in military, competitive and non competitive athletics [9]. In military, it is used to monitor the soldier's condition in the field.

In 1996, Wireless body area network (WBAN) was first presented by T. G. Zimmerman. So in April 2009 , IEEE P802.15 working group for wireless Personal area networks (WPANs) has developed a channel model (IEEE 802.15.6) for WBAN which is for medical and non-medical devices that could be placed inside or on the surface of human body[2] . The fading power profile is generated in terms of received power with respect to transmit power, which is based on NICTA's (National Information and Communication Technology Australia) measurement results[1].

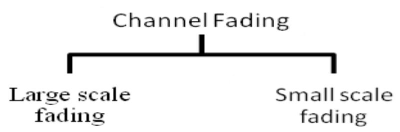
This paper is organized as follows . In the next section, brief description of WBAN channel model along with related parameters has been given. Subsequently, the simulation methodology to generate fading power profiles in WBAN channel scenarios has been described. The results are discussed in section 4 before the paper is finally concluded in section 5.

2. WBAN CHANNEL MODEL

In the WBAN, information propagates as electromagnetic waves from devices that are close to or inside the human body ,but human body is never an ideal medium for the propagation of radio waves. The human body consists of complex shaped various types of tissues having different dielectric constant, permittivity, conductivity and characteristic impedance .Therefore, propagating wave experiences fading which is caused by energy absorption, reflection , diffraction and shadowing by body tissues and body posture. The multipath due to the environment around the body is also one of the factors causing fading which makes the channel models for WBAN different from the ones in the other environments .
Transmitter and Receiver are the integral part of the WBAN channel. The static path loss and impulse response models for the wearable and implantable WBAN includes miniature antennas are presented in [19]. These models are already contributed to IEEE 802.15.6.This model is a statistical model and uses all the measurements carried out by NICTA at 820 Mhz. This paper uses the fading power profile of WBAN channel which includes fading and path losses. [1]

2.1 Fading
Fading is the process of destruction of the power of the signal or attenuation of the signal .In the WBAN it is caused by environment inside or outside the body . Fading can be small scale or large scale.

Small scale fading is in concern with rapid fluctuations in the amplitude and phase of the received signal within a small local area in small period of time due to small changes in location of the on-body device or body positions .It occurs due to variation in the relative position between transmitter and receiver [1].



Large scale fading refers to the signal attenuation due to mobility over larger areas .It occurs due to variation in distance covered by signal between antenna positioned on the body and external node(home, office, or hospital) because of diffraction from large surrounding objects.

2.2 Path Loss

In WBAN, path loss is both distance and frequency dependent .The dependency of body tissues on frequency is considered here. The path loss model between the transmitting and the receiving antennas can be represented as a function of the distance (d).Based on the Friis formula [3] in free space path loss in dB is expressed by equation (1) as follows:

$$PL(d) = PL_0 + 10n\log(\frac{d}{d_0}) \qquad (1)$$

Where PL_0 is the path loss at a reference distance d_0 , and n is the path – loss exponent .
The equation (1) represents increase in path loss with distance.

2.3 Shadowing

Shadowing is the process of blocking of signal by large objects which are encountered due to the variation in the environment surrounding the body or even due to movement of the body parts .It causes variation in path loss of signal from that of mean value for a given distance as shown in equation (1) .So this phenomenon of shadowing reflects the path loss variation around the mean. The shadowing should be considered for stationary and non - stationary position of body. When considering shadowing , the total path loss i.e. PL can be expressed by equation(2)[1]

$$PL = PL_0 + S \qquad (2)$$

Combining equation (1) and (2), total path loss is

$$PL = PL_0 + 10n\log\left(\frac{d}{d_0}\right) + S$$

3. SIMULATION METHODOLOGY

Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies and parameters for the operation of the system. However it is not possible to model every parameter of human body channel through commonly used formulas in other wireless channels because of its complex tissue structure but major parameters have been taken into considerations. Also measurement of various human body parameters is not an easy task. So it is necessary to design channel model using standard measurements and in this channel model all measurements , i.e. sample rate , spreading bandwidth etc , are taken from NICTA channel measurements . Since the performance analysis of the WBAN receiver is based on statistical model of the channel [3]. The simulation model is used here to statistically generate the fading power profile of WBAN channel[2] . In order to generate an initial signal, that matches the desired fading statistics using order statistics, the following steps are being used.

Step1: A set of Weibull distributed random numbers are generated according to best fit to signal statistical distribution around mean from NICTA's measurements.

Step2: Rayleigh fading power is generated by using Jake's model with an appropriate rate of fading.

Step3: Based on Weibull distributed random numbers , Weibull fading power profile is generated according to the ordering of the Rayleigh power profile.

After generation of initial signal it is manipulated by in such a way to make its fade depth statistics match those found in NICTA's measurements . The signal is treated in portions each portion being a fade followed by a non-fade (a contiguous portion of the signal above the mean power). All the signal portions are compared with the desired fade depth statistics.

The current signal portion is manipulated depending on this comparison in one of three ways:

Step 4: If generated signal (step 3) is best matches to desired fade depth statics (dfds), the current signal portion is kept as it is and it is inserted into the output signal.

Step 5: If generated signal (step 3) is highly attenuated to desired fade depth statics then the parts of signal having too much attenuation are discarded and rest of the signal is inserted into output.

Step 6: If generated signal (step 3) do not match with the desired fade depth statics then the whole signal is discarded.

Step 7: Adjust the final signal so its mean is equal to the mean specified by the user.

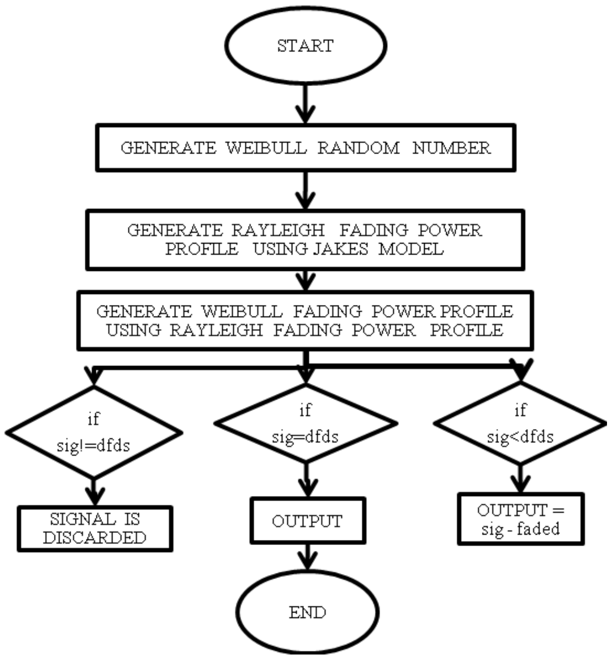


Figure1: Flow chart for generation of fading power profile [3].

All parameters used in the above simulation model are taken from NICTA measurements. Some of them are given in table1.

Table1. NICTA specifications for WBAN Parameter NICTA Specification Allowed Range

Parameter	NICTA specification	Allowed range
Carrier Frequency(f_c)	820MHz	420-2500MHz
Sample rate	1KHz	0.75-15KHz
Velocity	1.5-5.5km/h	1.5-20km/h

3.1 SIMULATION PARAMETERS

In order to evaluate the performance of WBAN channel under varied channel conditions, some important and effective simulation parameters have been identified in this work. They include:

3.1.1Carrier frequency: A carrier signal is a transmitted electromagnetic pulse or wave at a steady base frequency of alternation on which information can be imposed by increasing signal strength, varying the base frequency, varying the wave phase, or other means. This variation is called modulation. A carrier frequency is frequency of carrier signal.

3.1.2 Relative body movement: Relative body movement velocity is a rough approximation of receiver movement velocity with respect to scatterers and/or transmitter .It is used to generate a signal with an appropriate rate of fading in the signal sub function to main function of WBAN power profile function.

3.1.3 Scattering density : Scattering density is defined by the number of scatterers.Scatterers are some form of radiation, such as light, sound, or moving particles that are forced to deviate from a straight trajectory by one or more localized non-uniformities in the medium through which they pass.

4. RESULTS AND DISCUSSIONS

Extensive simulations have been carried out in this work to observe the variations of the channel fading in terms of scatterer density variation, carrier frequency and relative body movement velocity within the constraints specified by NICTA. From the description of the simulation model given in the previous section, fading power profile of WBAN channel for different values of **carrier frequency** have been plotted in figure 2 where x-axis is showing time(in seconds) and y-axis is showing channel gain(in db). Channel gain represents the gain in the power of the signal while transferring the data from transmitter end to receiver end. As the value of the channel gain is always negative in the graphs, it represent that there is loss in power of signal while travelling of signal from transmitter to receiver i.e. there is fading of the signal.

4.1 Carrier Frequency

The plots have been obtained by varying the carrier frequency in the range of 420-2500 MHz (as specified by NICTA) and taking constant value of velocity (1.5+4*rand), number of scatterers(100) and sample rate (1khz) . Here rand is a function which generates values between 0 and 1. It has been observed from the graphs that the channel is showing minimum fading at carrier frequency of 820 Mhz..

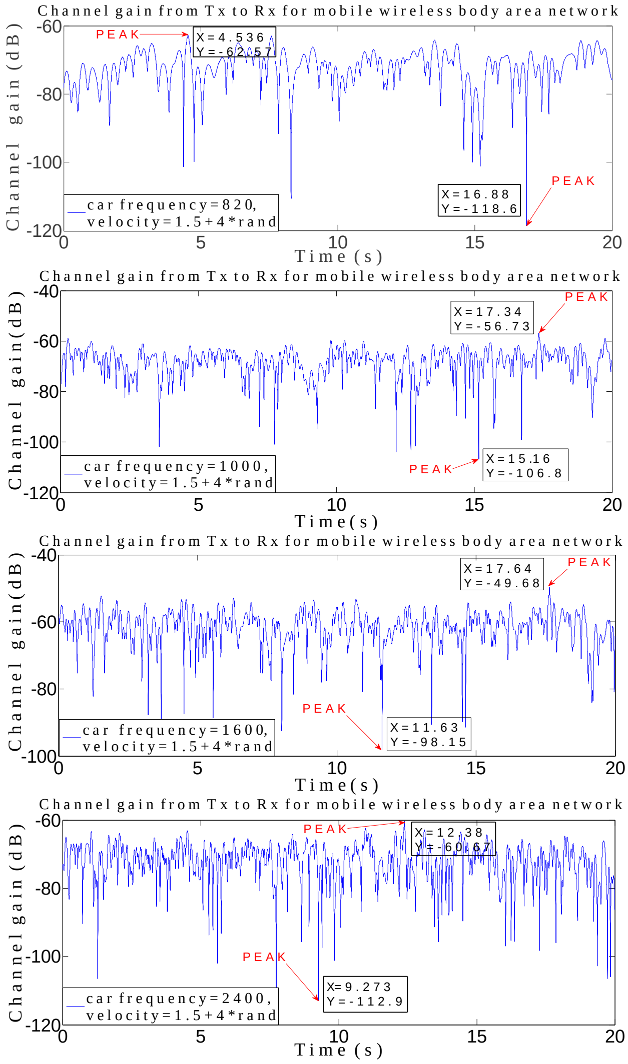


Figure2: Fading in WBAN at different carrier frequency.

For calculation of mean fading in table 2,the values of velocity=1.5+4*rand (rand function generate values from 0 to 1.), number of scatterers =100 and sample rate=1 khz are taken.

Table2: Mean fading for different carrier frequency.

S.No.	Carrier frequency(in Mhz)	Mean fading
1.	820	54.02
2.	1000	66.79
3.	1600	71.52
4.	2400	66.43

4.2 Relative Body Movement Velocity

In this section, fading power profile of WBAN channel have been plotted for different values of **relative body movement velocity** Figure3 shows fading power profile for different values of relative body movement velocity. In this case velocity is varied in the range of 1.5-20 km/h. The plots have been obtained by varying the relative body movement velocity in this range. It has been observed from the channel gain profile that on increasing the velocity, the fading is also increasing and the calculated value of mean fading which is shown in table 3 also satisfies our observations.

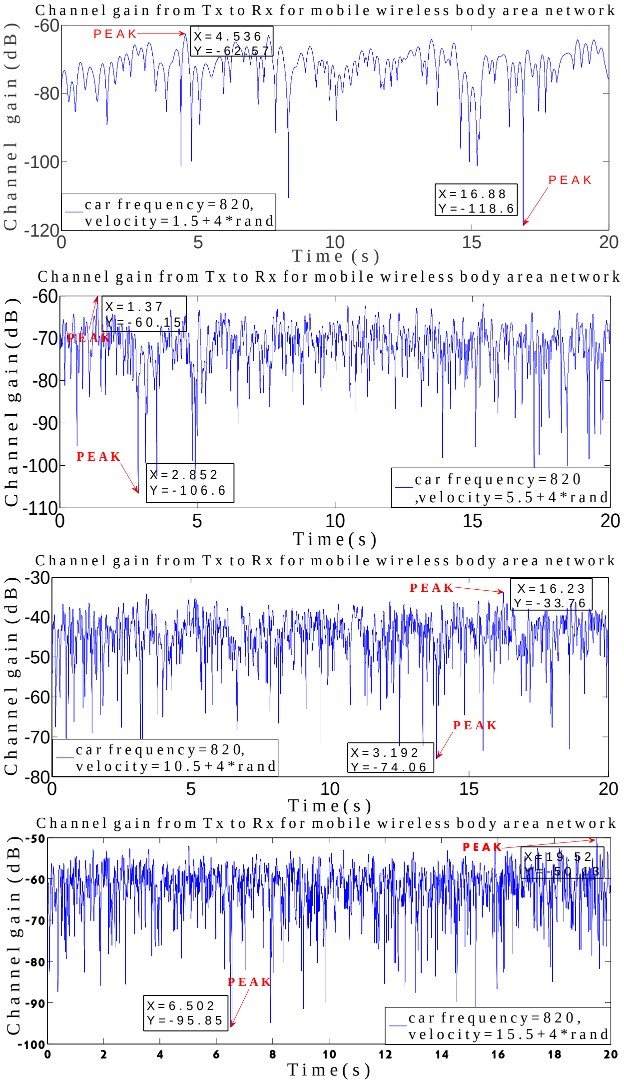


Figure 3:Fading in WBAN channel at different values of relative body movement velocity.

For calculation of mean fading in table 3,the values of carrier frequency=820 Mhz, number of scatterers =100 and sample rate=1 khz are taken.

Table 3:Effect of relative movement of body on mean fading.

S.No.	Velocity	Mean fading
1.	1.5+4*rand	64.33
2.	5.5+4*rand	66.12
3.	10.5+4*rand	72.14
4.	15.5+4*rand	75.90

4.3 Scatterer Density

This section presents the fading power profile of WBAN channel which have been plotted for different values of **number of scatterers[20]**. Figure 4 shows the fading power profile by variation in scatterers around the body. It has been observed that fading in the channel gets increased by increasing the number of scatterers due to increase in scattering density.

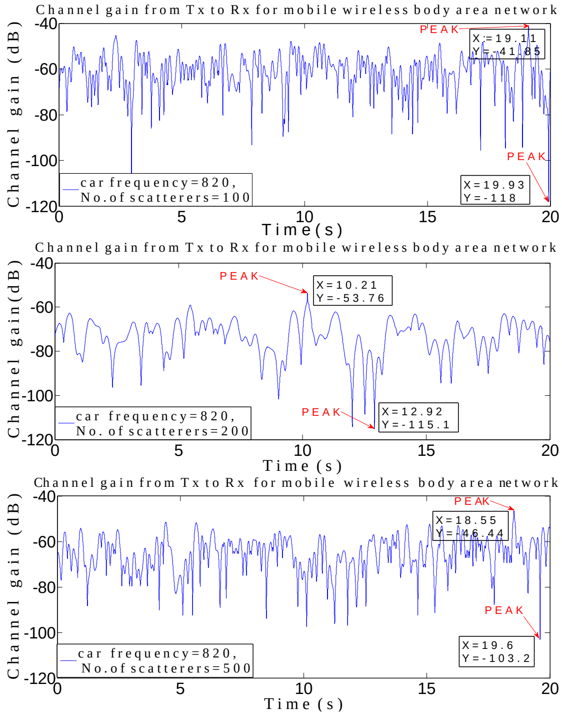


Figure 4: Fading in WBAN channel with the variation in scatterers.

For calculation of mean fading in table 4,the values of velocity=1.5+4*rand, carrier frequency=820 Mhz. and sample rate=1 khz are taken.

Table 4: Effect of variation in scatterers around the body on mean fading.

S.No.	Number of scatterers	Mean fading
1.	100	56.74
2.	200	63.23
3.	500	74.62

5. CONCLUSION

WBAN seems to be very prominent technology in the near future and various applications are being designed based on this technology in the health care sector. However there are various design challenges ahead of communication engineers to enable the WBAN based applications a reality. So in this work, extensive simulations have been carried out considering parameters like carrier frequency, relative body movement velocity and scatterers density. The results obtained in this paper regarding aforesaid parameters are: minimum value of mean fading is obtained in WBAN channel for the carrier frequency - 820 Mhz., velocity-1.5+4*rand (i.e. 1.5-5.5 km/h) and number of scatterers-100. Hence, it can be concluded that when carrier frequency is 820 MHz. relative body movement velocity is in the range of 1.5-5.5km/hr and number of scatterers is 100, the WBAN channel will works effectively. Thus, the results obtained in this paper will be of great help in facilitating the network designers for systematic planning of the WBAN based products in the future.

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