In-vivo Characterisation and Numerical Analysis of the THz Radio Channel for Nanoscale Body-Centric Wireless Networks

Ke Yang, Akram Alomainy and Yang Hao
School of Electronic Engineer and Computer Science
Queen Mary University of London
London, UK
{ky300;akram.alomainy;yang.hao}@eecs.qmul.ac.uk

***Abstract*—Analytical investigations are presented to calculate the path loss and absorption coefficients of human tissues such as blood and fat at THz frequencies as an essential part of understanding nanoscale networks. From the results, it can be seen that with the rise of the distance and frequency, the path loss increases slightly as expected. For the blood, the path loss at 1mm is around 100dB while for the fat the corresponding distance to the path loss of 100dB is approximately 2mm, leading to the conclusion that at very short distances, in the order of millimeters, the path loss is not significantly high to consider communication between nano-devices.**

I. INTRODUCTION

Although the nano-network has been gained great advancement, the communication between nano-devices is still an open issue. So far, two paradigms are mainly made use of to complete the communication process: molecular communication[1] and electromagnetic communication[2]. Although the molecular one is totally biocompatible and suitable for nano-scale, the communication distance is short, or else the channel will be unreliable with the big communication time delay[3], which can be addressed by the electromagnetic communication. Reference [2] discusses the possibility of EM communication on the basis of the fact that THz band can be used as the operation frequency range for future EM nano-transceivers because of the characteristics of graphene[4]. The propagation model for THz communication at nano-scale is developed in [5] and at the same time the capacity of such channel is analyzed. A simple communication mechanism is presented in [6] while later new Medium Access Control (MAC) protocols are described in [7].

However, in-vivo communication at THz has not been studied even though the feasibility of using THz to communicate is validated[5] and the optical parameters of human tissues up to 2.5 THz are demonstrated in [8, 9]. Therefore, the path loss is calculated in this paper to check if it is possible for THz waves to propagate in vivo.

II. THEORETICAL MODEL

From the modified Friis equation, the total path loss PL can be presented as follows:

$$PL[dB] = PL_{spr}[dB] + PL_{abs}[dB] \tag{1}$$

Where, PL_{spr} is the spread loss due to the expansion and propagation of the wave in the medium while PL_{abs} stands for the loss due to the medium absorption.

PL_{spr} can be obtained as follows:

$$PL_{spr} = 20\log_{10}\frac{4\pi d}{\lambda_g} \tag{2}$$

Where, d represents the total path length;

λ_g is the wavelength in the medium, which is the ratio of the free space wavelength, λ_0, to the refractive index of the material, n:

$$\lambda_g = \frac{\lambda_0}{n} \tag{3}$$

PL_{abs} can be calculated as follows:

$$PL_{abs} = 10\alpha d \log_{10} e \tag{4}$$

Where α is the absorption coefficient which can be induced from the extinction coefficient, K:

$$\alpha = \frac{4\pi \mathrm{K}}{\lambda_0} \tag{5}$$

The extinction coefficient K measures the amount of absorption loss of the electromagnetic wave when it passes through the medium.

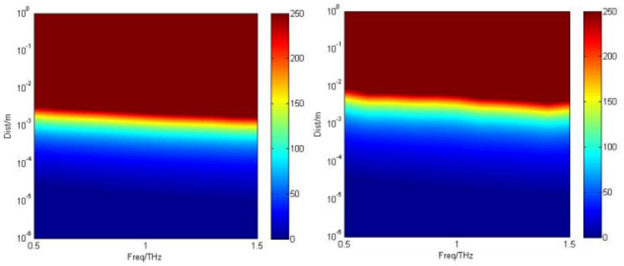
The refractive index n and extinction coefficient K can be obtained from the measurement. Meanwhile, they also can be calculated from the dielectric parameters of the materials:

$$\begin{cases} n = \sqrt{\dfrac{\sqrt{\varepsilon'^2 + \varepsilon''^2} + \varepsilon'}{2}} \\ \mathrm{K} = \sqrt{\dfrac{\sqrt{\varepsilon'^2 + \varepsilon''^2} - \varepsilon'}{2}} \end{cases} \tag{6}$$

Where, ε' represents the real part of the relative permittivity of the material while ε'' stands for the imaginary part.

III. PATH LOSS ESTIMATION AND CHARACTERISATION

From the parameters demonstrated in [8, 9] and the formulae above, the path loss in blood and fat is calculated, shown in Fig. 1.



a blood b fat

Figure 1. Ttotal path loss in dB vs. frequency and distance

From the figures above, it can be seen that for different tissues, the path loss is different because of the different parameters. For blood, the path loss of the distance below 1mm is decent while in fat the wave can travel farther. Even though the distance is not very long, in the order of millimeters, it is still supposed to be enough for the nano-communication. At the same time, we can see that the path loss increases with the rise of the frequency and distance, as expected. But on the other hand, the path loss does not increase much when the frequency goes up. Unlike in [5], the fluctuation is not observed, which is probably due to the fact that the blood is treated as homogeneous and the sample rate for the frequency is too low. It is believed that the concentration of the blood cell has an impact on the channel performance which will be studied later.

IV. CONCLUSION

With the development of the nano-network, the methods for nano-devices to communicate have been discussed recently. During this time, the molecular communication has gained much attention while few people study the electromagnetic method. On the basis of the previous work, a method to calculate the path loss in vivo is proposed and the corresponding results show that at the level of millimeters the path loss is not significantly high leading to the possibility of the electromagnetic communication between nano-devices.

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