STATISTICAL PARAMETERS OF NARROWBAND CHANNELS ON THE WALKING HUMAN

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ABSTRACT

Measurement of the temporal variation of the Rician fading model parameters are described that give an indication of the relative significance of the direct ray and the scattering off the body and from the local environment. The measurements of the walking human, were conducted at 2.45 GHz both in an anechoic chamber and a typical office environment. The results indicate that for the belt to head channel, the scattering from the body can be generally neglected, unless the subject is outdoors in a clear environment. A suitable model may then be created using the strongest ray strength obtained from simulation using a homogeneous phantom in free space and the environmental scattering from simulation or measurement of the antennas in the environment without the body. However in the belt to wrist channel, there are times when body scattering dominates and must be included in the model. The results also give good insight into the mechanisms involved and may also allow extrapolation to other body movements.

1 INTRODUCTION

Body centric wireless communication is now accepted as an important part of the 4th generation (and beyond) mobile communications systems taking the form of human to human networking incorporating wearable sensors and communications [1,2]. In these body area network communications channels, propagation will involve wave interaction with the body, in addition to scattering from the local environment. Modelling of such on-body channels has been the subject of much interest, both in terms of statistical characterisation and computer modelling, [3-6]. This paper describes recent work at the University of Birmingham on the combination of such methods which might allow future prediction of channel characteristics.

2 CHANNEL CHARACTERISATION

Channels from the belt to the head and to the wrist have been characterised at 2.45 GHz, using a number of different practical antennas. Path gain data was recorded using portable equipment on two subjects who walked about an office environment. The data was analysed by separating into fast and slow fading and statistical models were fitted using the χ^2 test. Table I gives some results for the belt to wrist channel. Parameters for the belt to head channel show similar characteristics. Parameters shown are for fast fading s, σ and K, which characterise the strongest ray power, s^2, the average scattered power, $2\sigma^2$, and the ratio of the power in the strongest ray to the average scattered power, $K = s^2/2\sigma^2$, respectively. Fast fading showed good fitting for the Rician model for all cases. The strongest ray power is greatest for the monopoles and PIFAs, as they are polarised normal to the body

Table I Parameters of statistical models for fast and slow fading in belt-to-wrist channel.

Subject	***Antennas***	***Fast fading - Rician***			***Slow fading – lognormal***	
		s (dB)	σ (dB)	K (dB)	μ (dB)	σ_S (dB)
Male	Monopoles	-1.2	-9.8	5.6	-45.3	1.4
	Dipoles	-2.7	-7.0	1.3	-74.0	2.6
	Loops	-3.2	-6.8	0.6	-68.2	2.8
	PIFAs	-1.5	-9.5	4.9	-56.0	2.1
	IFAs	-2.6	-7.3	1.7	-69.2	2.8
Female	Monopoles	-0.2	-17.5	14.3	-42.9	1.5

surface. Scattering is strongest where the direct ray is less and the variations of K are strongly dependent on the antenna type and the activity of the body. The female subject walked with very little arm movement and this resulted in a very high K value. For the slow fading envelope the mean, μ, and the standard deviation, σ_S, are shown. Fitting for slow fading was less good with the majority being lognormal. The range of standard deviations is relatively small, from 1.3 to 2.8 dB. Parameter μ, which represents the average PG, on the other hand, has large differences. It is the highest for the monopoles in both channels and is at least 10 dB lower for other antennas.

3 VARIATION OF ON-BODY CHANNEL PARAMETERS DURING WALKING

It has been shown, [7], that good agreement can be obtained between measured PG and that simulated using phantoms created using animation software. The simulations were done for a walking human and without environmental scattering, which simplified the simulation. This was the equivalent of a human in an anechoic chamber and modelled both the direct ray where this was present and scattering and multipath on the body. Averaging over many measurements, and some simulation points, was necessary to get agreement, due to the difficulty of getting the subject to exactly adopt the position of the phantom in the simulation. It is believed that this averaging removed the multipath fading present in both the measurement and the simulation as well as the variations caused by the differences between the posture of the human and the phantom. This suggested that a channel model which was based on the statistical parameters of the channel for any given posture could be useful for characterising the channel during arbitrary body movements.

The results of Section 2 showed that the received signal envelope can be represented as a product of two components one of which (fast fading) randomly fluctuates according to a Rician distribution, and the other (slow fading) is approximately lognormal. Equivalently, the envelope can also be considered as Rician with the parameters s and σ (or Ω and K) being random slowly changing variables themselves. It can then be hypothesized that there are three components of the average received power: power of the strongest (direct) ray, s^2, average power delivered by the multipath components propagating around the body itself, $2\sigma_B^2$, and the average power scattered from the objects in the environment surrounding the body, $2\sigma_E^2$. Then, providing these parameters can be derived by measurements or simulations, the statistics of the signal envelope for an on-body channel in an environment is known to be Rician with the parameters s and σ, where $\sigma^2 = \sigma_B^2 + \sigma_E^2$.

The parameters s and σ_B can be derived by fitting a set of PG data measured on a person in an anechoic environment or simulated on a human phantom in isolation. The parameter σ_E can also be derived empirically or by simulating the antennas in the environment. In such a simulation the antenna properties,

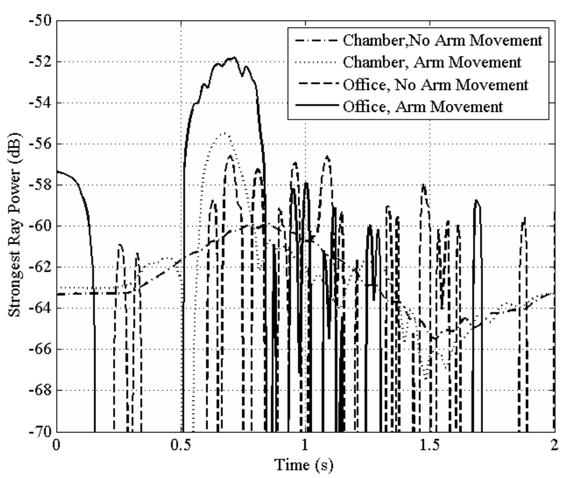

Fig 1 Strongest ray power, s^2, for belt-to-head channel

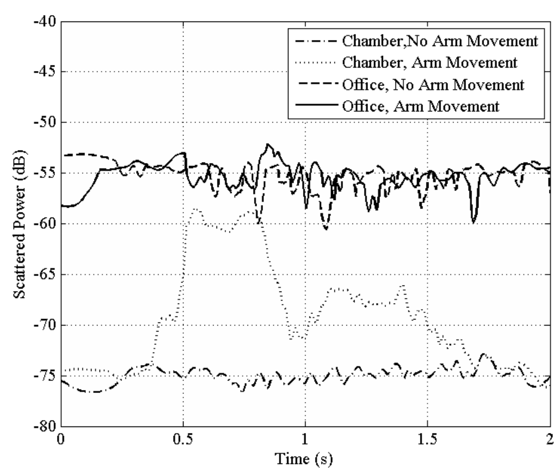

Fig 2 Average scattered power, $2\sigma^2$, for belt-to-head channel

such as efficiency, gain and radiation pattern, have to be those for the antennas mounted on the body, but the body itself may be excluded from the simulations, thus greatly simplifying the calculations and allowing use of such methods as ray-tracing.

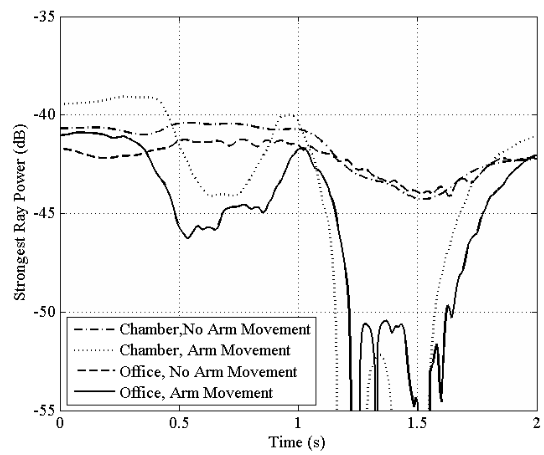

Fig 3 Strongest ray power, s^2, for belt-to-wrist channel

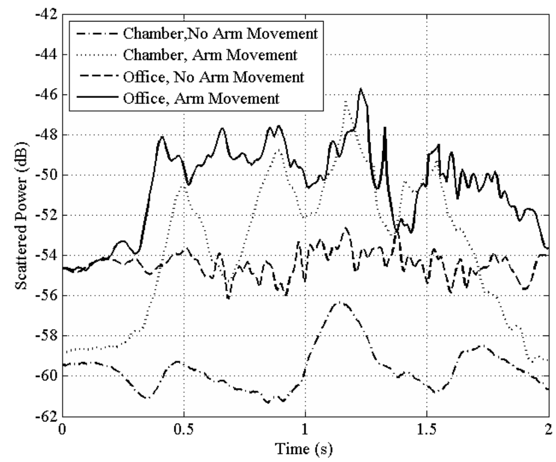

Fig 4 Average scattered power, $2\sigma^2$, for belt-to-wrist channel

The parameters for walking activity for the head and wrist channels can be estimated from a set of repeated and synchronised walk measurements. One pace of walking was repeated 100 times, both in the anechoic chamber and in a cluttered office environment, with and without arm movement, for the belt to head and belt to wrist channels. The Rician distribution was fitted to each set of 100 data points at any given moment during the pace. The variation of the Rician parameters was then observed as the pace progressed in time.

Figs. 1 and 3 show s for the head and wrist channels, respectively, for the two environments and two walking styles, and Figs. 2 and 4 show $2\sigma^2$, where $\sigma^2 = \sigma_B^2$ in the anechoic chamber, and $\sigma^2 = \sigma_B^2+\sigma_E^2$ in the office. The abrupt variation of the parameter s in Figs. 1 and 3 is probably due to parameter estimation errors noticeable when s is small.

Fig. 2 shows that scattering from the office environment dominates scattering from the body itself in the head channel, with scattering in the office averaging about -55 dB and in the chamber -75 dB, except when the arm movement increases body scattering to -60 dB. On the other hand, it can be seen from the chamber results in Figs. 1 and 2 that s^2 dominates $2\sigma_B^2$, with s^2 averaging more than -64 dB with arm movement, compared to an average $2\sigma_B^2$ of -70 dB. Therefore, for this channel it is sufficient to obtain the mean power received on the body in isolation and the mean power in the environment without the body, both of which can be done by simulations. Scattering from the environment appears to be the main contributor to the received power in this channel, except in the interval around 0.6 s when the right arm is held forward providing a strong reflected path. Comparing the curves for the two walking styles in the chamber in Fig. 2 demonstrates the presence of the multipath around the body.

For the wrist channel when there is no arm movement, Figs 3 and 4, the direct ray averages -42 dB and dominates both scattering from the body, at -60 dB average, and from the office environment, at -54 dB average, by at least 10 dB. This also shows that σ_E dominates σ_B by about 5 dB. Hence, in this case σ_B can also be neglected as in the case of the head channel. However, when the arms move forward (time before 1 s) s decreases since the direct path is obstructed by the arm wearing the antenna, but the scattering from the body increases and can become even stronger than that from the environment. The same effect is also present and is even stronger when the arm moves back (time after 1 s) and the direct path is well obstructed by the body while other paths around the body become stronger.

4 CONCLUSIONS

Characterisation of the belt to head and belt to wrist body area network channels at 2.45 GHz, during the walking activity, show fast fading that is always Rician and slow fading that is best fitted by a variety of models which are often lognormal. When the slow fading is characterised as a parameter variation during the walk, the contributions from the direct, or strongest ray, body scattering and environmental scattering can be established, by comparing results from the anechoic chamber and the office. The results indicate how simulation or measurement can be used to model the walking activity. For example, in the belt to head channel, body scattering can be ignored. A suitable model may then be created using the strongest ray strength obtained from simulation using a homogeneous phantom in free space and the environmental scattering from simulation or measurement of the antennas in the environment without the body. However in the belt to wrist channel, there are times when body scattering dominates and must be included in the model. Obtaining this from simulation has yet to be demonstrated.

6 ACKNOWLDGEMENTS

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