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ANTENNAS AND PROPAGATION FOR BODY CENTRIC COMMUNICATIONS

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Abstract

Body centric wireless communication is now accepted as an important part of 4th generation mobile communications systems. The design of antennas and the characterisation of radiowave propagation on the body are now being considered, by many groups around the world. The paper gives a brief overview of the current position and reports on some recent advances in the topic.

1 Introduction

Body centric wireless communication is now accepted as an important part of 4th generation mobile communications systems and will be part of the forthcoming convergence and personalization across the various domains, which include personal area networks, (PANs), and body area networks, (BANs). Advancements in the miniaturisation of wearable hardware, embedded software, digital signal processing, and biomedical engineering have made it practically possible for human to human networking incorporating wearable sensors and communications. This can be seen as a continuation of a trend spearheaded by the mobile phone, which, over the last few decades has become smaller and more convenient for personalized operation. Alongside this trend, there have been a number of body centric communication systems for specialized occupations such as paramedics and fire-fighters, as well as continuing interest for military personnel. Use for medical sensing and support, with either skin mounted sensors or implants, is also attracting much attention.

To support these developments there has been considerable research into antennas and propagation for body centric communications systems. This paper will summarise some of it and give an overview of the work at the University of Birmingham. There is much interest in the characterisation of the channel on the body, and in the optimisation of antennas for these channels. Characterisation is happening at relatively low frequencies of a few MHz and also at microwave frequencies where higher data rates can be supported. Ultra wide bandwidth systems may also be advantageous on the body and both antenna design and measurement of path loss and dispersion effects is in progress. Conventional antennas such as the monopole, patch and PIFA are being examined for these applications to achieve low link loss in the face of extreme body geometry changes. Fabric based antennas also show exciting possibilities. Similar research is also being conducted on communications into medical implants where advanced antenna design and characterisation and modelling of the channel are important research needs. In all of these areas both measurement and simulation pose very different and challenging issues to be faced by the researcher.

2 Antennas

Antennas for body centric communications have been summarised well in recent publications, [1-5], including antennas for 10 MHz body surface communications, [6], button antennas, [7-9], wearable antennas for mobile communications, [10-12], and wearable antennas for FM radio reception and other applications, [13,14]. Antenna requirements will be determined largely by the functionality required. In particular for off-body communications, then radiation away from the body to improve channel path gain and reduce SAR is important. For on-body links then antennas that direct the radiation along the body surface with the appropriate polarisation are needed. Finally for implant communications the implant antenna will be highly constrained by the implant size and the need to use low frequencies to reduce the tissue loss.

These statements are however generalisations and specification of detailed requirements are usually hard to give. In all cases, the antenna size will be determined by the application and by equipment design constraints. Whilst bandwidth is determined by the system or by spectrum allocations, it is very difficult to specify radiation pattern requirements, beyond those given above. This is primarily due to the dynamic nature of the body whose shape is continuously changing as the person goes about their activities. However, this is somewhat like the situation with antennas for mobile phones, where the antenna size, bandwidth, efficiency and SAR are the primary parameters. By way of example, whilst previous initial work has indicated that for links between antennas on the body should have a monopolar like pattern with polarisation oriented normal to the body surface for maximum path gain, the choice may depend on higher order statistics if these are important. Table 1 shows measured results for three antenna types, a quarter wave monopole on a small ground plane, a more compact top loaded monopole and a planar inverted antenna (PIFA). The antennas have been measured in many positions on the body and in many local environments, using portable measuring equipment located in a small rucksack on the person's back. It can be seen that whilst the monopole give best path gain, the PIFA has lowest fading (range) and fade duration. If these characteristics are more important than path gain, then the PIFA may be the best choice.

3 Propagation

3.1 Channel Characterisation

Radiowave propagation studied have been reported by several groups, [1], where characterisation of signal fall-off with distance, path gain mean, and higher order statistics have been determined at several frequencies. So far results for only a few body types have been presented; results for large people and children have not been reported.

3.2 Interference Between BANs

Body area networks will not operate in isolation, but may operate in close proximity to many other such networks. There will be, of

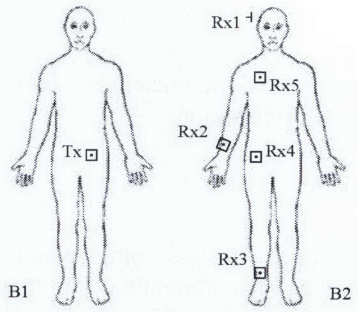

Fig. 1. Antenna positions

course, a need for these networks to communicate with each other. At the same time it is necessary to maximise isolation between the on-body links to maximise their capacity and efficiency. Although primary interference control will be through coding and protocols, we have examined the isolation at an RF level. Figure 1 shows the experimental arrangement. The transmitter is on the belt of body 1 and the receiver at various positions on body two.

Table 2 shows results of measurements at 2.45 GHz and 5.8 GHz. The antennas are positioned as indicated and then measurements of S21 taken whilst the bodies adopted a series of different postures. Post processing gives the path gain mean and its standard deviation, together with average fading duration (AFD) and level crossing rate (LCR). Finally statistical fitting was done and the best fit model is indicated.

Antennas Type	Statistics Parameters					
	Mean	Median	Std	Range	AFD*	LCR**
Top loaded monopole	-47.3	-46.9	6.67	**64.2**	0.116	0.621
Monopole	**-44.4**	**-43.0**	**7.96**	64.0	**0.169**	**0.735**
PIFA	-56.3	-56.8	7.02	55.7	0.096	0.640

Table 1. Performance of three antenna types for many channels and environments for each type of antennas
(*AFD at -10dB fade depth from the median value
**LCR at -10dB fade depth from the median value)

Freq	Channels		Distances (meters)	Statistics Parameters				
				Mean	Std	AFD	LCR	
2.45GHz	Left-Trunk (b1)	Right-Head (b2)	1.5	-49.7	6.07	0.163	0.533	Weibull
			3	-50.5	6.06	0.208	0.593	Nakagami
		Right-Wrist (b2)	1.5	-51.1	7.47	0.209	1.067	Nakagami
			3	-58.4	7.35	0.181	0.682	Gamma
		Right-Ankle (b2)	1.5	-48.8	4.53	0.197	0.119	Rician
			3	-57.8	5.78	0.131	0.741	Gamma
		Right-Trunk (b2)	1.5	-49.2	6.37	0.164	0.385	Weibull
			3	-53.3	7.00	0.263	0.444	Nakagami
		Right-Chest (b2)	1.5	-47.1	5.13	0.145	0.207	Weibull
			3	-52.6	5.91	0.179	0.652	Rayleigh
5.8GHz	Left-Trunk (b1)	Right-Head (b2)	1.5	-56.9	7.25	0.200	0.267	Nakagami
			3	-60.9	6.70	0.173	0.444	Nakagami
		Right-Wrist (b2)	1.5	-61.9	9.43	0.150	0.622	Weibull
			3	-66.9	8.83	0.184	0.978	Lognormal
		Right-Ankle (b2)	1.5	-54.6	6.47	0.225	0.444	Weibull
			3	-61.0	7.39	0.178	0.563	Nakagami
		Right-Trunk (b2)	1.5	-53.1	5.76	0.122	0.356	Rician
			3	-58.5	5.61	0.143	0.652	Gamma
		Right-Chest (b2)	1.5	-56.7	6.62	0.137	0.415	Nakagami
			3	-59.5	6.50	0.230	0.741	Nakagami

Table 2, Statistics Parameters for Random Activities for 1.5 and 3 meters distances at 2.45GHz and 5.8GHz

3.3 Diversity on the body

It has recently been shown at the University of Birmingham that there are some links on the body that would benefit from diversity. Although there is some multipath fading on a stationary body, it is primarily body movement that gives rise to fading. Table 3 shows the diversity gain in two channels obtained by using a diversity antenna consisting of two quarter wavelength monopoles spaced by 5.3 cm on a continuous ground plane. The transmit antenna was located on the belt.

It can be seen that the diversity gain is greater for the belt to head channel than the belt to ankle. For other postures, such as standing or sitting, the diversity gain is, in general, less. The best gain of just over 10, for maximal ratio combining on the head channel, is significant from a systems point of view. However the antennas used are large and some size reduction is necessary.

Currently experiments using a disc loaded monopole parasitic beam switching array, [15], are in progress to try to quantify the diversity gain using pattern switching. Using this antenna direction of arrival statistics for various on-body channels has been determined which support the hypothesis that there is multipath on the body, but may only be due to a few dominant paths.

Diversity Gain	RX placement right head	RX placement Ankle
SC	8.57	5.14
EGC	9.62	6.13
MRC	10.28	6.46

Table 3 Diversity Gain at 2.45GHz for jogging postures
(SC = selection combining, EGC = equal gain combining, MRC = maximal ratio combining)

6 References

1. Hall, P S and Hao, Y, (editors) "Antennas and Propagation for Body Centric Communications Systems", (Artech House, Norwood, MA, USA, 2006, ISBN-10: 1-58053-493-7)
2. Hall, P S and Hao, Y, "Antennas and |Propagation for body centric communications", European Conference on Antennas and Propagation, EuCAP06, Nice, France, Nov 2006
3. Hall, P S, "Antenna challenges for body centric communications", *IEEE Int.Workshop on Antenna Technology, IWAT*, Cambridge, 2007.
4. Kamarudin, M R, Nechayev, Y I and Hall, P S, "Performance of antennas in the on body environment", IEEE AP-S International Symposium, Washington, USA, July 2005
5. Salim, T Z and Hall, P S, "Efficiency Measurement of Antennas for On-Body Communications", Microwave and Optical technology Letters, vol 48, no 11, Nov 2006, pp 2256-2259
6. K. Fujii , M. Takahashi, K. Ito & N. Inagaki, "Study on the Electric Field Distributions around Whole Body Model with a Wearable Device Using the Human Body as a Transmission Channel", European Conference on Antennas and Propagation, EuCAP06, Nice, France, Nov 2006
7. B.Sanz-Izquierdo, F.Huang and J.C.Batchelor, "Dual band button antennas for wearable applications", *IEEE Int.Workshop on Antenna Technology, IWAT*, New York,2006
8. B.Sanz-Izquierdo, J.C.Batchelor and M Sohby, "Compact UWB wearable antenna", Loughborough Antennas and Propagation Conference, Loughborough, UK, 2-3 April 2007,.
9. B.Sanz-Izquierdo, P.R.Young, Q.Bai and J.C.Batchelor, "Compact UWB monople for multilayer applications", *Electronics. Lett*ers, 5th January 2006, Vol.42,No1, pp 5-7
10. P. Salonen & Y. Rahmat-Samii, "Textile Antennas: Effects of Antenna Bending on Input Matching and Impedance Bandwidth", European Conference on Antennas and Propagation, EuCAP06, Nice, France, Nov 2006
11. M. Klemm & G. Tröster, "Textile UWB Antennas for On-Body Communications", European Conference on Antennas and Propagation, EuCAP06, Nice, France, Nov 2006
12. Zhu, S, Liu, L and Langley, R, "Dual band body worn antenna", Loughborough Antennas and Propagation Conference, Loughborough, UK, 2-3 April 2007,.
13. T. Kellomaki, J. Heikkinen, M. Kivikoski, "Wearable Antennas For FM Reception", European Conference on Antennas and Propagation, EuCAP06, Nice, France, Nov 2006
14. Toosi, K N, "VHF-LB vest antenna design", *IEEE Int.Workshop on Antenna Technology, IWAT*, Cambridge, 2007.
15. Kamarudin, M R and Hall, P S, " Diversity measurements of antennas in the on-body environment", European Conference on Antennas and Propagation, EuCAP06, Nice, France, Nov 2006