11

ANTENNA MEASUREMENTS IN THE ON-BODY ENVIRONMENT

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11.1 INTRODUCTION

On-body communication system is very important especially for the 4th Generation Mobile Communication. Such system use two or more devices that connected to each other wirelessly and using human body as a support environment to place the wearable devices, as shown in Figure 1l.1. User acceptability factors should be considered at the first place in designing wearable devices.

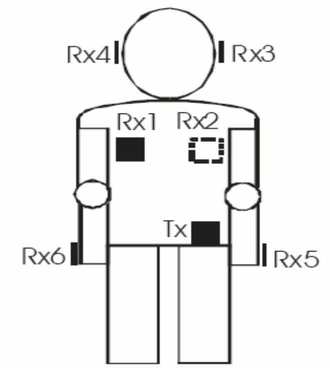
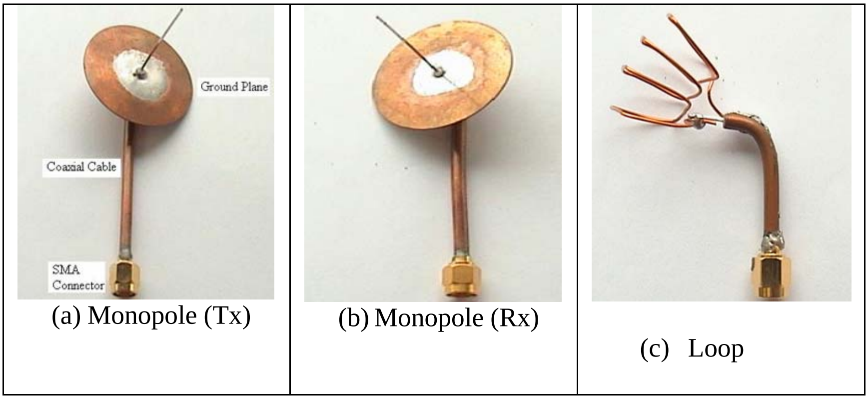


Figure 11.1 Possible locations for wearable devices

11.2 ANTENNAS DESIGN

There are several types of antennas have been designed in this work as shown in Figure 11.2 and Figure 11.3. The most important requirements for antennas for on-body communications are the antenna sensitivity to the human body and the antenna radiation pattern. These two factors imply that the antenna should be insensitive to the proximity to the human body and it needs to have a radiation pattern shape that can minimize the channel loss.



(a) Monopole (Tx) (b) Monopole (Rx) (c) Loop

Figure 11.2 Types of On-Body antennas

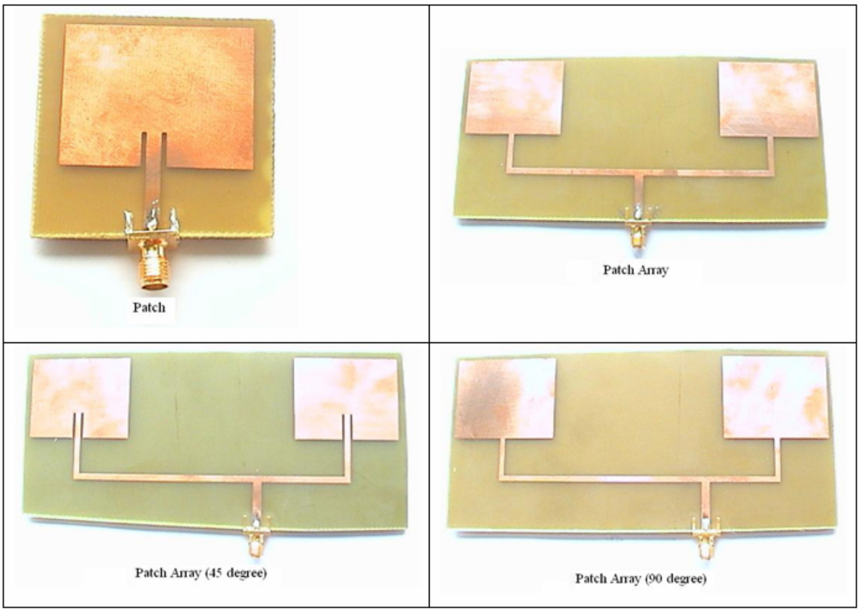


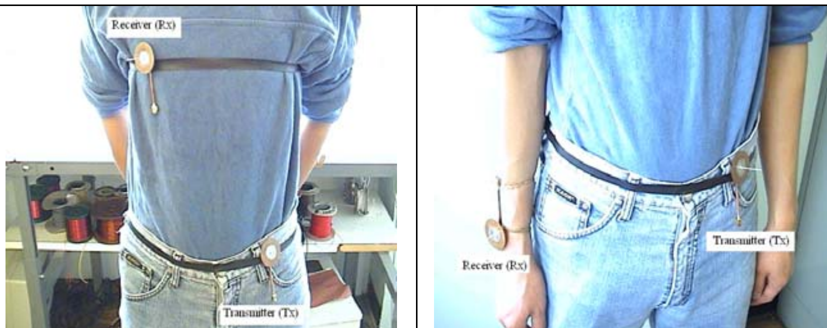
Figure 11.3 Printed antenna types used for on-body measurement

The loop and monopole antennas are chosen due to their advantages in providing omnidirectional patterns with maximum radiation along the surface, but with H and E fields normal to the surface, respectively. These will be suitable for paths where the surface wave dominates and in particular the monopole has a polarization, which matches that of the surface ware. Since patch antenna produces strong radiation in the direction that normal to the radiating patch so it is more suitable for the free space channels. The arrays with various beam tilts were used as it is clear that in some circumstances the paths in the belt wrist case are not normal to the body surface. In all cases radiation into the body should be minimized, as the relatively small skin depth of a few centimeters at these frequencies suggests that little energy is propagated through the body. Due to the large number of possible channel geometries and body postures so it is very difficult to specify ideal antenna characteristics. Thus, the results presented in this chapter only focus on the estimation to be made of the best antenna type and for how many body postures this will give optimized results.

11.3 ON-BODY CHANNEL MEASUREMENTS

Channel loss has been measured by placing antennas at various points on the body as shown in Figure l1.4. In this figure, monopole antennas are shown. Fig l1.4 (b) shows antennas on belt and wrist. For channel loss measurements, the antennas are connected to a Network Analyzer through two 2m long, flexible, phase and amplitude stable, cables. The transmitting antenna is put on the belt while the receiving antennas are placed on the chest and wrist. Antenna and cable mountings are such not to impede body movement, as propagation characterization measurements have shown that channel loss is very sensitive to body posture and movement.

This measurement had also illustrated that the channel loss was very dependent on both antenna types and the channel geometry. Channel geometry can be described as the relative positions of the transmitting and receiving antenna. It also determines the propagation mode. For instance, for the belt to chest channel, the propagation mode seems to be dominated by a surface wave. Meanwhile for the belt to wrist channel, there will be in some cases of a free space path when the hand is in front of the body, and a shadowed free space path with diffraction around the body when the arm is behind the body. In the case of a surface wave, it is clear that an antenna with a radiation pattern maximum along the body surface and with vertical polarization is needed.



(a) Belt-to-Chest Channel (b) Belt-to-Wrist Channel

Figure 11.4 Placement of the antennas on the body

11.4 CHANNEL PERFORMANCE

Figure 11.5 shows measured path gain for the belt to chest path for various antennas. It can be seen from the key that one antenna is always a monopole whilst the other is changed. The path gain varies by around one or two dB within each 20 second period, but this is averaged in the figure. The posture changes are given in the caption. It is clear that for all postures the monopole-to-monopole combination gives the best result, as expected. Meanwhile, Figure 11.6 shows the measured path gain for the belt to wrist case, for the same conditions. It can be seen that the variation of loss is much greater than in the belt to chest case, and for several postures the array with beam tilt gives better results.

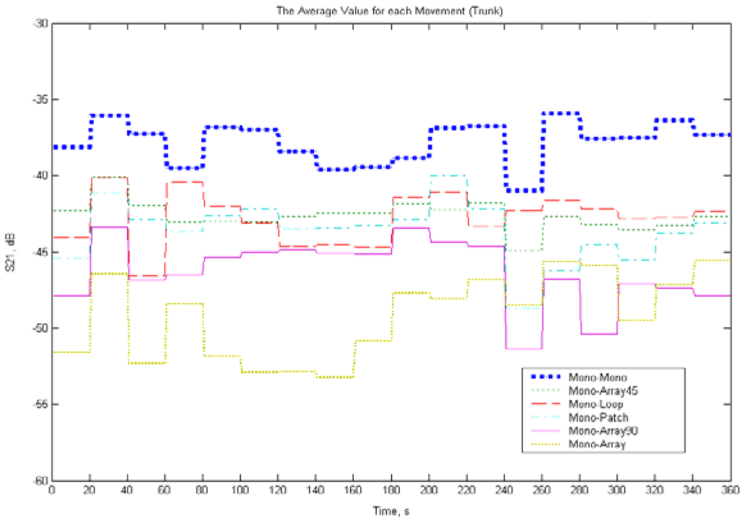


Figure 11.5 Measured Path Gain for Belt-to-Chest Channel for Variuos Body Posture. Inset show the combinations of the antennas and the receiving antenna orientations

Frequency = 2.45GHz; Loss averaged over 20sec posture period; Postures: 0-20 standing; 20-40 standing, body turned left; 40-60 standing, body turned right; 60-80 standing, body bent forward; 80-100 standing, head bent forward; 100-120 standing, head turned left;120-140 standing, head turned right; 140-160 standing, arms stretched out to side; 160-180 standing, arms above head; 180-200 standing, arms forward; 200-220 standing, forearms forward; 220-240 standing freely*; 240-260 sitting, arms hanging; 260-280 sitting, hands on lap; 280-300 sitting freely*; 300-320 standing; 320-340 walking, arms close to body; 340-360 walking, arms swinging free.(*freely means arbitrary position)

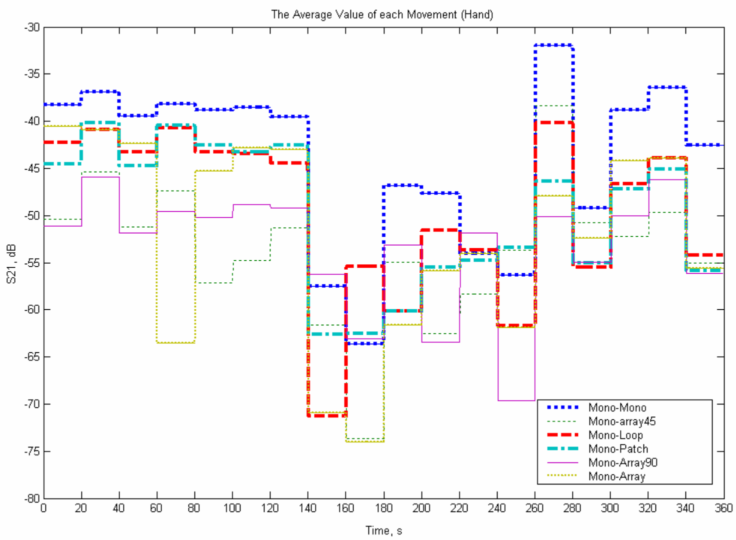


Figure 11.6 Measured Path Gain for Belt-to-Wrist Channel. (Conditions as in caption Figure 11.5)

Figure 11.7 compares measurements to calculations using a first order model, based on the Friis propagation loss expression. The channel geometry and length for each posture is estimated. The antenna gains including polarization loss are found from measured radiation pattern. Free space propagation is assumed. In general calculated results underestimate the loss, but are within l0dB of measurements. In some cases involving movement, such as for period 220-240 and 340-360 seconds, two calculations are made based on a least and greatest loss at the movement extremes. In these cases, the calculation extremes are close to the extreme measurements.

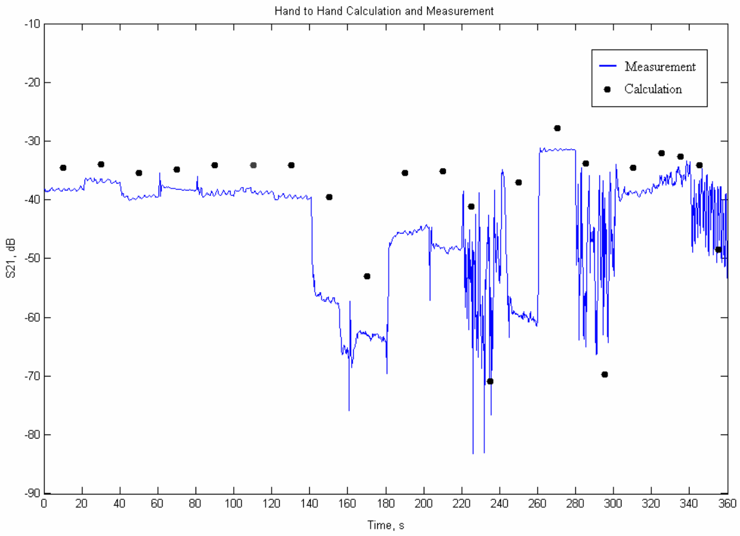


Figure 11.7 Measured and Calculated Path Gain for Belt-to-Wrist Channel with Two Monopole Antennas. (Conditions as in caption Figure 11.5).

11.5 CONCLUSIONS

In this chapter results for 6 different transmit and receive antenna combinations over two body channels have been presented. The results show that for most of the cases here the monopole - monopole combination gives lowest channel loss. Measurements and calculations have been presented that allow choice of best antenna type for on body communication channels. However this study is by no means exhaustive. Many move body paths need to be considered and further optimization of the antenna may be possible.

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