MEASUREMENT OF LOCAL ENVIROMENTAL EFFECTS IN UWB CHANNELS

Murat D. VURAL(1), Mehmet YILDIZ(2), Ali KARA(2)

(1)Synplicity Ar-Ge Ltd, Ankara Tekn. Ge. B., Cyberpark A308 Bilkent-Ankara, TURKEY, murat@synplicity.com
(2)Atilim University, Electrical-Electronics Engineering Department, 06836 Incek- Ankara, TURKEY, myildiz@atilim.edu.tr, akara@atilim.edu.tr

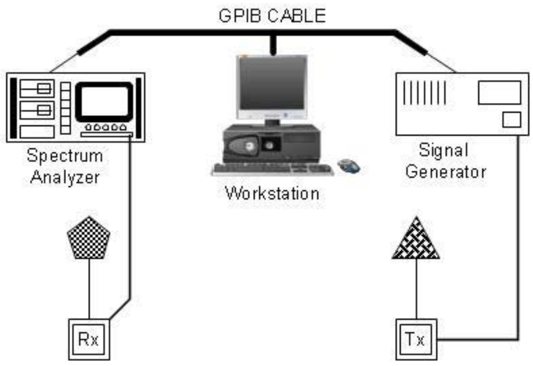
1. INTRODUCTION

Ultra wide-band (UWB) takes great attention all over the world, for its promising features and solutions for short range connectivity for wireless networks, sensors, geo-location and radar applications [1,2]. Since UWB is very favourable low power, short-range indoor communications technology, channel characteristics of UWB links must be studied and understood for indoor environments before getting on field. Understanding of local environmental conditions near the terminals is important for determining system performance and possible interference in UWB channels [3,4]. Besides the static objects made of different kind of materials in environments, human beings in the vicinity of UWB links have also an impact over UWB links [5,6]. When people move in the vicinity of the link they cause fading, which may be the result of body blockage or multipath interference due to body scattering. As the number of mobile devices used indoor environment increases, such as PDAs, wireless VoIP phones which are used very close to humans, the effect of humans on wireless links increases dramatically.

This study presents measurement results on the effect of local environmental objects, and in particular, human bodies in and around UWB radio links. The paper is organized as follows; section II describes the measurement system and environment. Section III presents measurement results on human body shadowing, and is followed by conclusions.

2. MEASUREMENT SYSTEM AND ENVIRONMENT

The CW measurement system consists of receiver and transmitter sections, and very similar to the set-up used in [5, 6]. The transmitter is a CW signal generator connected to a triangular monopole while the receiver is a spectrum analyzer connected to a receiving monopole identical to the transmitting one. The system is controlled through software running on the PC, to which the system is connected via GPIB interface as shown in Figure 1(a). The receiver is configured such that the measured peak power is at least 20 dB above the noise floor in order to see possible deep fades when the link is fully blocked.



(a)

(b)

Figure 1. Outdoor Measurements

Calibration measurements were made in a large open area outdoor, a tennis court as shown in Figure 1(b). The details of outdoor measurements and the triangular monopole antennas that were designed for use in the measurements were presented in [7]. Human body blockage was studied at different frequencies at 2.5 – 11.5GHz band in both indoor and outdoor environments. The transmitting and receiving antenna heights are determined such that the human body blockage be maximum. An example of the received signal power variation for human body blockage in Figure 1 is shown in Figure 2 where the frequency was set to 5.5GHz, and antenna heights were 1.19m.

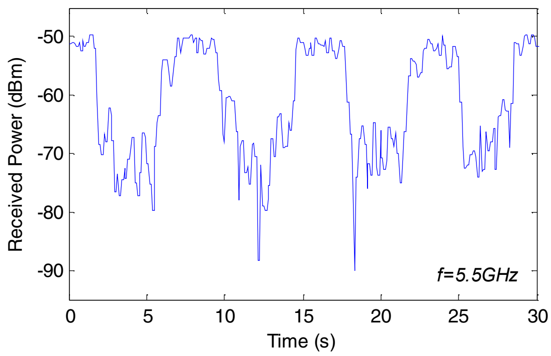


Figure 2. Received signal variation when radio link is continuously blocked by human body.

Indoor measurements were made in the laboratories of Electrical and Electronics Engineering Department at Atilim University. Figure 2 shows a detailed view of the rooms used in the measurements. The rooms' walls are made of plasterboard, and the floors are concrete. The main room (F4) is 9m by 7m with ceiling height of 3.5m. It has two doorways which were closed during the measurements.

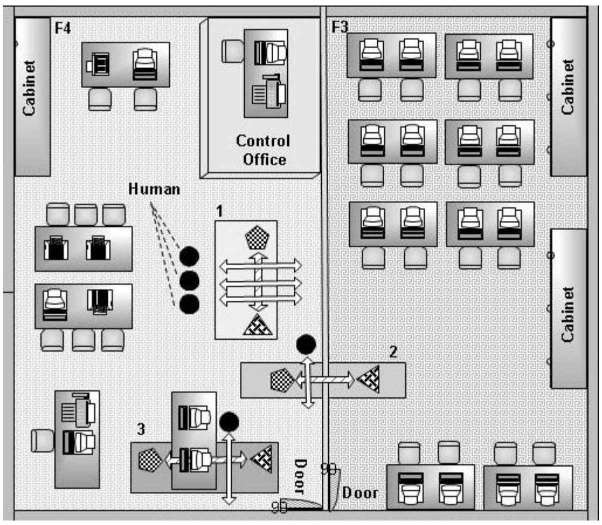


Figure 3. Floor plan of the laboratory environment

Three different scenarios were considered in indoor measurements that were labeled #1, #2 and #3 in Figure 3. Black balls represent people crossing the radio link, and their routes are also indicated by arrows. The transmitting and receiving antenna heights were 1.19m for scenario #1, and 1.3m for the others to obtain maximum blockage by the human body. In scenario #1, human body blockage was studied without any additional objects around the link. In this scenario, one and then three adults crossed the radio link continuously. In scenario #2 and #3, an adult crossed the radio link when there was also a wall in the link (#2), or a computer with its peripherals in the link (#3) as shown in Figure 3. In all cases, the transmitter was tuned at different frequencies, and the measurement was repeated for each frequency by recording the received signal for duration of 20-40s. The environment has been assumed to be static during the measurements since the only motion was the people crossing the radio links. The speed of motion for people crossing the link was determined appropriately by considering the response time of the receiver, and estimated Doppler spread for indoor environments [6].

2. MEASUREMENT RESULTS

2.1. Human body shadowing

When people move in and around the radio link, they cause fading as a result of multipath interference or shadowing effects due to body scattering. When the radio link is blocked by human body in microwave frequencies, radio waves propagating through body can usually be neglected due to very small depth of penetration, and the most contributing components would be the radio waves diffracting around the human body, and reflecting from around nearby objects [8]. In outdoor measurements, human body shadowing was studied when there were no objects around the radio link. The dominant factor was due to the diffracting of radio waves around human body as shown in Figure 2. On the other hand, the scenario labeled #1 in Figure 3 illustrates the case when nearby objects are considered along with human body blockage. In this case, both diffracting around the body and reflecting from nearby objects would contribute to the received signal as shown in Figure 4. The duration and depth of fades are correlated with the blocking rate of the person, and at full blockage fades of 10 dB or even more were observed at 5.5 GHz.

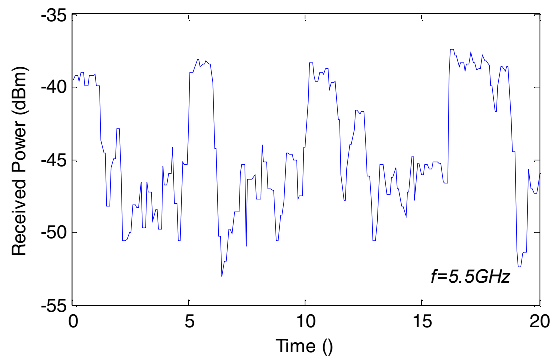
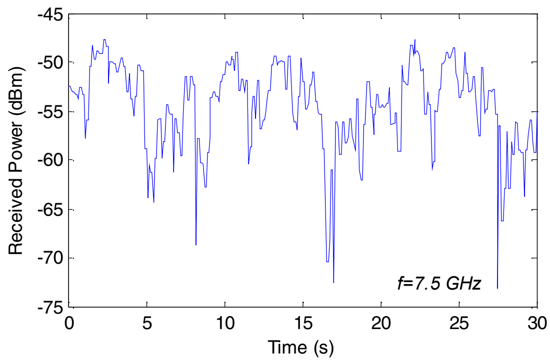


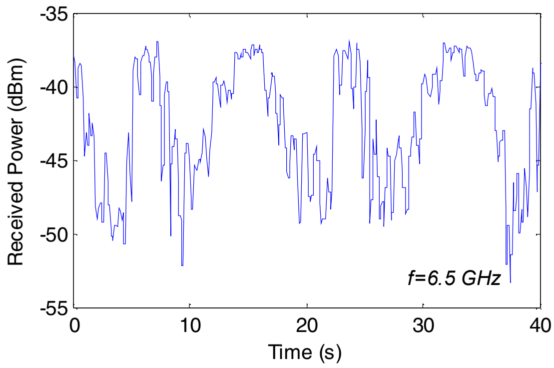
Figure 4. Received signal variation when radio link is continuously blocked by human body.

2.2. Human body shadowing with nearby objects

In the experiments, human body blockage along with other local environmental objects in and around the radio link was also considered. Scenario #2 was one of which simulates situation when the transmitter and the receiver was obstructed by both a wall and an adult crossing the radio link continuously as illustrated in Figure 3. The scenario #3 simulates the practical cases when office equipment, like PCs, together with people moving around obstructs the radio links in UWB systems. In both cases, the effects of human body blockage is less perceptible in the plots compared with the case when only human body shadowing is considered as shown in Figure 6. When the radio link is obstructed by a wall in addition to human body, fades due to human body blockage becomes imperceptible at some frequencies. This suggests that human body shadowing has of great importance for indoor LOS channels.



(a) Scenario #2



(b) Scenario #3

Figure 6. Received signal variations for #2 and #3.

2.3. Statistical analysis of shadowing

In path loss for radio propagation in wireless channels, the shadowing (or shadow fading) is usually a parameter introduced as the variation of range-dependent path loss (or amplitude) from the median value at a particular distance or location. The distribution of shadowing has been reported to be log-normal (Gaussian with dB power) in most of the measurements [8-10], and its probability density function (PDF) is given by [10]

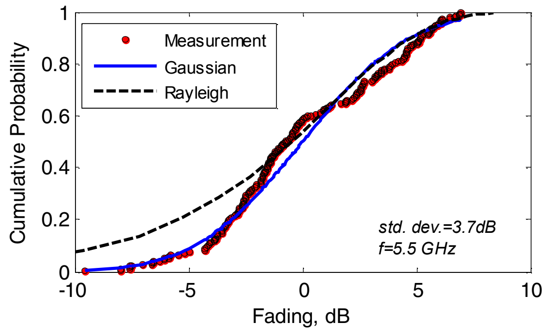
$$p(U_i - <U>) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left[\frac{-(U_i - <U>)^2}{2\sigma^2}\right] \quad (1)$$

where U_i is the power in dB, $<U>$ is the mean value of the power, and σ is the standard deviation. Cumulative distribution function (CDF) can be obtained via

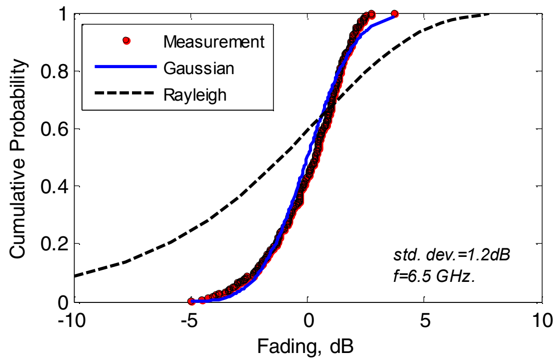
$$P(U_i < u) = \int_{-\infty}^{u} p(U_i - <U>) dU_i \quad (2)$$

for given standard deviation of σ.

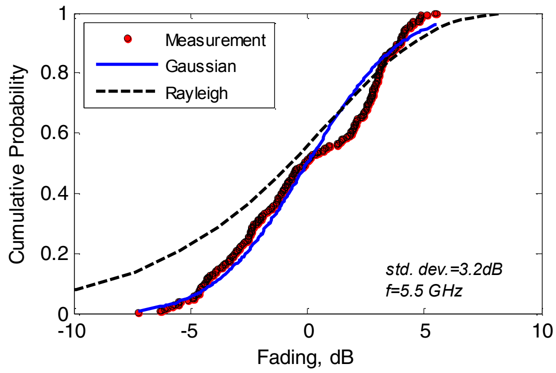
In order to analyze the distribution of human body shadowing in the experiments, CDF in (2) is constructed for first scenario. Figure 7 shows the CDF constructed for scenario #1, #2 and finally #3 at different frequencies. For each case, Gaussian (log-normal) and Rayleigh CDFs with the same standard deviations are also plotted for comparison.



(a) #1



(b) #2



(c) #3

Figure 7. CDFs for different scenarios of Figure 3.

3. CONCLUSION

The effects of local objects and in particular, human body shadowing in and around radio link on the UWB channels have been studied. In outdoor environments, human body blockage causes deep fades, and is perceptible. In indoor environments, since there are objects nearby the radio link, radio waves diffracting around the body and reflecting from nearby objects would contribute to the received signal, and fades margin is relatively smaller than the outdoor case. When the radio link is blocked by human body, the duration and depth of fades are correlated with the blocking rate of the person, and at full blockage fades of 10-15 dB or even more are observed at different frequencies. When the link is obstructed by a wall (or other objects) in addition to human body, fades due to human body blockage becomes imperceptible at some frequencies.

The shadowing (or shadow fading) is usually a parameter introduced as the variation of range-dependent path loss from the median value at a particular distance or location. The distribution of shadowing has been reported to be log-normal (Gaussian with dB power) in most of the measurements. The distribution of human body shadowing has been analyzed by constructing the CDF given by (2) for different radio links at different frequencies. As reported in [8-10], human body shadowing follows the log-normal distribution in most of the cases in the experiments.

4. REFERENCES

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