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INFLUENCE OF HUMAN BODY ON RADIO SIGNAL STRENGTH INDICATOR READINGS IN INDOOR POSITIONING SYSTEMS

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Abstract

In this paper the basic assumptions of a Radio Signal Strength Indicator – based fingerprint and the influence of human body on the results are presented. The main focus is put on the influence of the obstruction of line-of-sight between access point and transceiver by a human body. This issue must be corrected in order to gain more accurate and reliable results of the positioning. The mathematical model for correction of this issue is proposed along with some examples. The examples are based on the real measurements made by authors. Presented correction formula allows to minimize the influence of the user – access point direction on the results obtained during fingerprint creation and positioning.

Introduction

The positioning systems based on a Radio Signal Strength Indicator (RSSI) are widely described and had been investigated by many authors (GANSEMER 2010, SHEN et al. 2005, KUO et al. 2010). They can operate using one of available wireless communication systems like WiFi, Bluetooth, ZigBee or XBee. There is a lot of phenomena connected with electromagnetic wave propagation, that can cause the RSSI reading to vary. One of them is the

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attenuation and diffraction of the signal caused by a human body. When a person is holding a hand-held transceiver the direction to the access point (AP) can be obstructed by his body (Fig. 1). This will have a significant influence on the RSSI reading.

The radio signal is propagated according to the Friis equation (FRIIS 1946), which can be presented in its simplest form as:

$$\frac{P_r}{P_t} = G_r G_t \left(\frac{\lambda}{4\pi R}\right)^2 \tag{1}$$

where:
P_r – received signal strength,
P_t – transmitted signal strength,
G_t – transmitter antenna gain,
G_r – receiver antenna gain,
λ – wavelength,
R – receiver – transmitter distance.

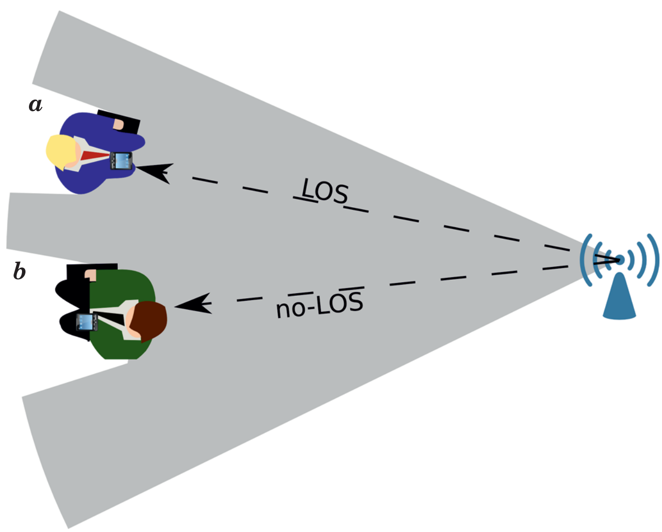

Fig. 1. Human body obstructing the LOS propagation: a – has line of sight, b – is obstructed by the users body

This equation is only true in theoretical ideal conditions. It assumes that a) the wavelength λ is much smaller than the distance R, b) the antennas are unobstructed and there is no multipath present, c) there is no impedance mismatch, no misalignment of polarization and no signal loss on the cables between transceivers and antennas. Because of this simplifications the equation cannot be directly used for distance calculation and range-based positioning (like trilateration). This is the reason for which the fingerprint methods were invented. In this methods the distance to the AP is not calculated and the positioning is based on matching the users observations with preliminary prepared maps of RSSI.

RSSI mapping

The RSSI parameter is defined in IEEE Standards Association (2012) and its characterization and description is available for example in BARDWELL (2004). The original use of this parameter was to establish a threshold for the wireless communication rather than positioning. This parameter has its limitations which results from its origins and compact size of communication devices. The most important issue is that the RSSI is not defined in a strict way. The IEEE Standards Association (2012) defines this parameter as a value between 0 and $RSSI_{max}$, where nothing is said about the value of $RSSI_{max}$. Therefore the upper limit of the RSSI value depends on the manufacturer of the transceiver. The resolution of the reading is device-dependent and affect the positioning accuracy. The dependency between IEEE 802.11 RSSI value and signal strength in dBm for various integrated circuit manufacturers is presented in Figure 2.

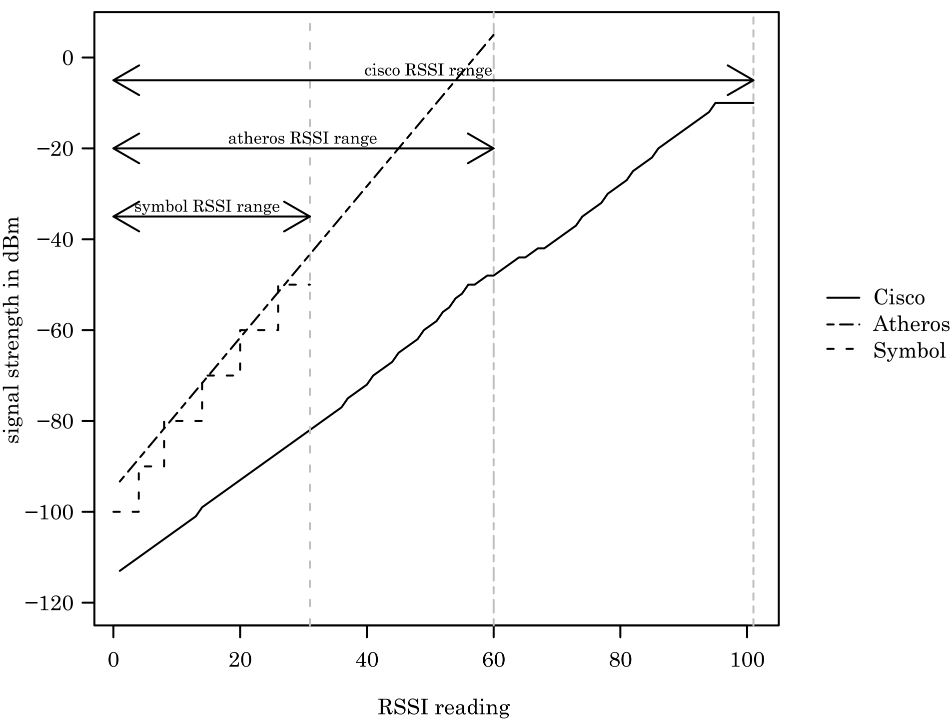

Fig. 2. Dependency between IEEE 802.11 RSSI value and signal strength in dBm for various integrated circuit manufacturers

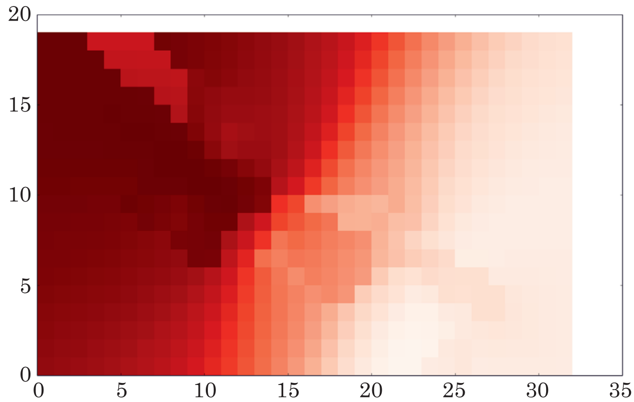

Fig. 3. Example of a heatmap for a single AP (dark = strong signal, light = light signal)

In the fingerprint method mapping of the RSSI of a considered area is required. The idea is to obtain a spatially distributed map of RSSI readings. The pre-surveyed values of the signal strength can be represented as a heat-map. The collection of the data for a heat map must be performed in a uniform way using the same device. Two ways of achieving the data are possible – by sampling the RSSI values in a uniform grid or by sampling in non uniform way and interpolating. Another option is to use the irregular heat map (points with corresponding RSSI values) as a nodes to which the positioning algorithm will try to „snap" the users location. The example of a heat map for a single AP is presented in Figure 3, where darker color represents stronger signal.

Positioning

The RSSI maps are created for each visible AP. The vector of signal strength values collected during localization is compared to these maps. User position is assumed in the place where the probed values are most closest (or most similar) to RSSI maps. This is illustrated in Figure 4 in which three heat maps from three AP's (AP1, AP2, AP3) are compared with the data collected for the positioning purpose. This values corresponds with the location marked with vertical line. To find users location the distance between collected data sample and heat map values must be calculated in the RSSI space. This can be done by using an euclidean distance:

$$\bar{d}_{\mathrm{RSSI}} = \sqrt{\sum_{i=1}^{n} (\mathrm{RSSI}_i^s - \mathrm{RSSI}_i^{hm})^2} \tag{2}$$

or Manhattan distance:

$$\bar{d}_{\mathrm{RSSI}} = \sum_{i=1}^{n} \left| \mathrm{RSSI}_i^s - \mathrm{RSSI}_i^{hm} \right| \tag{3}$$

where:
n is the number of access points (or heat maps), RSSI_i^s is collected RSSI value for i-th AP and RSSI_i^{hm} is the RSSI value read from i-th heat map. After calculating this distance in each node of the heat map, the cumulative heat map of distances can be created (Fig. 5). The minimum value of this heat map corresponds to user location.

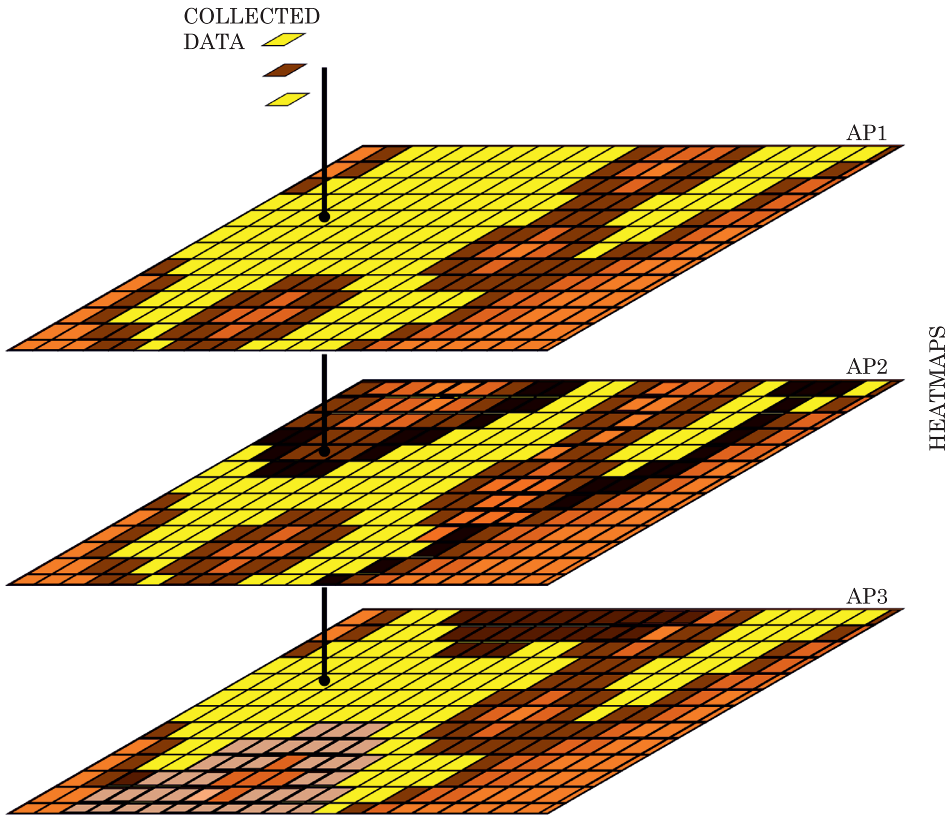

Fig. 4. The idea of heat-map comparison

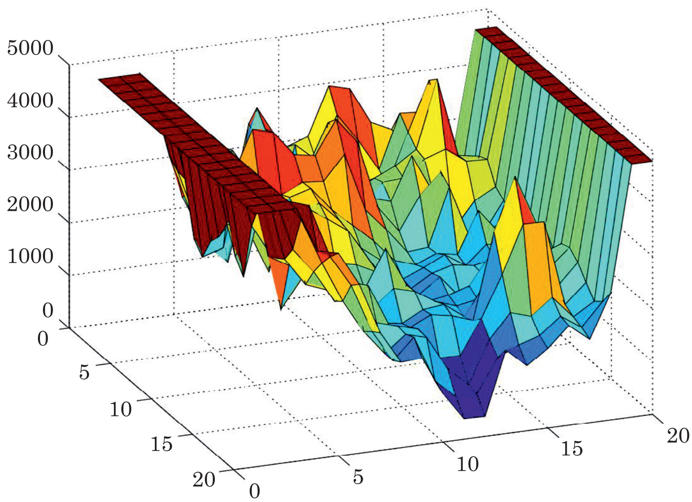

Fig. 5. Cumulative heat map

RSSI corrections

The positioning using the RSSI fingerprint is suitable for use in the indoor environment. In the modern society, hand-held devices (like smartphones or tablets) are very popular and can be easily adapted for such positioning system. Built-in Wi-Fi and Bluetooth transceivers can read the RSSI value and dedicated software can calculate users position. Hand-held device is usually held in front of the user. This is causing the attenuation of the signal from AP-s that are behind a user (since this signals does not propagate through human body) (CHEFFENA 2012). This can cause the situation in which the signal to one or more AP is read incorrectly, which can lead to incorrect result of positioning. The differences between the value of RSSI read in the line of sight and obstructed by user at different distances are depictede in Figure 6.

The measurements for Figure 6 were made in the multipath free environment, and still the difference in signal strength varies from 10 to 20 dBm. To investigate if this effect is caused by the human body attenuation only, or this shows combined effect of human body attenuation and antenna radiation pattern, two measurements were made. In the first one only the smartphone was rotated, and RSSI data to a single AP was collected. Results are shown in Figure 7. Looking at this figure, there is no regular attenuation at any angle, only noise is visible.

The second measurement involved rotation of a person holding a smartphone in front of him. The results are depicted in Figure 8. In this figure the maximum attenuation at about 70 degrees is noticeable, which is exactly at the oposite side of the AP. It means that this effect is caused by attenuation and/or diffraction of signal caused by a human body.

To mitigate this effect, a modelling of the intensification of signal strength can be introduced. The model should intensify the signal coming from the azimuths on the back side of a user. The formula for the correction term should reflect changes in the signal strength with respect to the angle between the user and an AP. It should amplify the readings for the APs that are behind user and leave the signal from the line-of-sight APs unchanged. Our proposal is the use of the following function:

$$\mathrm{RSSI}_{\mathrm{corrected}} = \mathrm{RSSI}\left(-\frac{k}{\sigma}\, e^{\frac{-(\alpha-180)^2}{2\sigma^2}} + 1\right) \tag{4}$$

where α is a user to AP azimuth, σ parameter describes the width of the intensification curve and k is a parameter describing the amount of „flattening" of the signal behind user. In the presented examples the parameters were chosen empirically to be $\sigma = 35$ and $k = 6$. The readings presented in the examples were made using WiFi signal. Linksys E900 Wireless-N300 router was used as a source of the signal and Samsung Galaxy S4 as a receiver. The results of application of this model to RSSI readings presented in Figure 8 is presented in Figure 9. Figures 10 and 11 depicts the correction function in different conditions (with different k parameter).

It can be noticed that the attenuation caused by a human body obstructing the line of sight is corrected, and only a certain amount of noise is visible. From the empirical experiments made by authors, the σ parameter fixed at the value of 35 is correct for any person and environment. The k parameter depends on the environment and should be derived during the process of fingerprint creation.

Conclusions

The method to mitigate the influence of the human body (of a person holding a smartphone) on RSSI reading is presented in this paper. Since the attenuation varies with rotation angle, neglecting this effect can cause different positioning results for a person standing in the same place depending on his or her heading. Application of the proposed formula, gives the possibility to mitigate this effect which can lead to improvement in positioning accuracy and reliability.

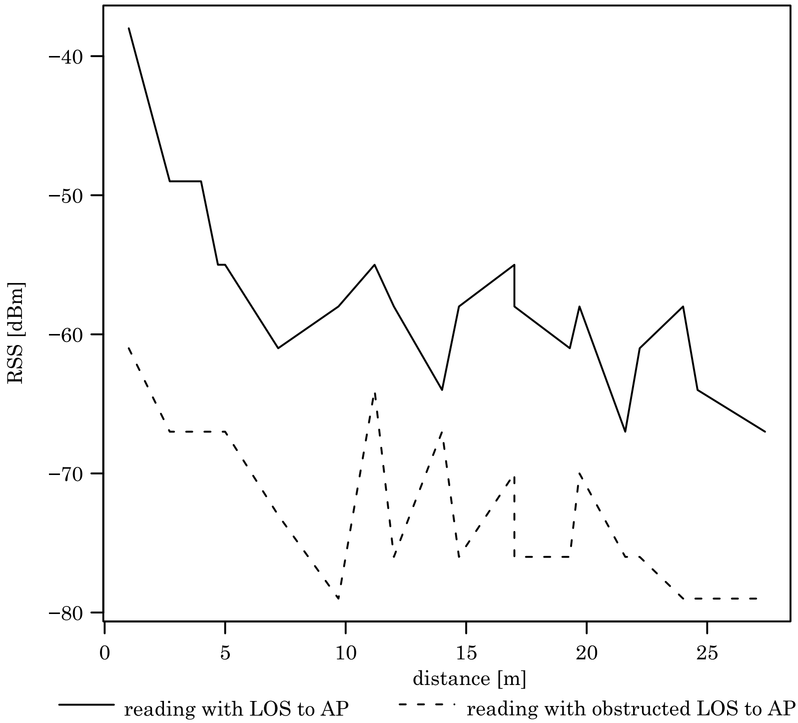

Fig. 6. Influence of a human body obstructions on the signal strength measurement

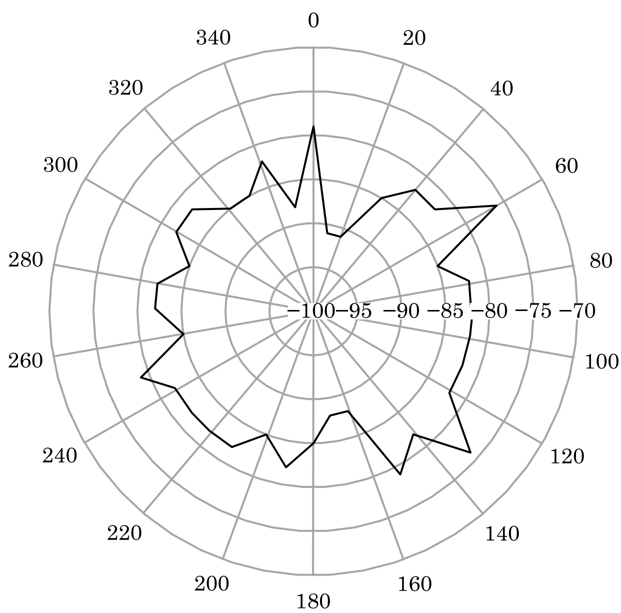

Fig. 7. RSSI [dBm] vs smartphone rotation

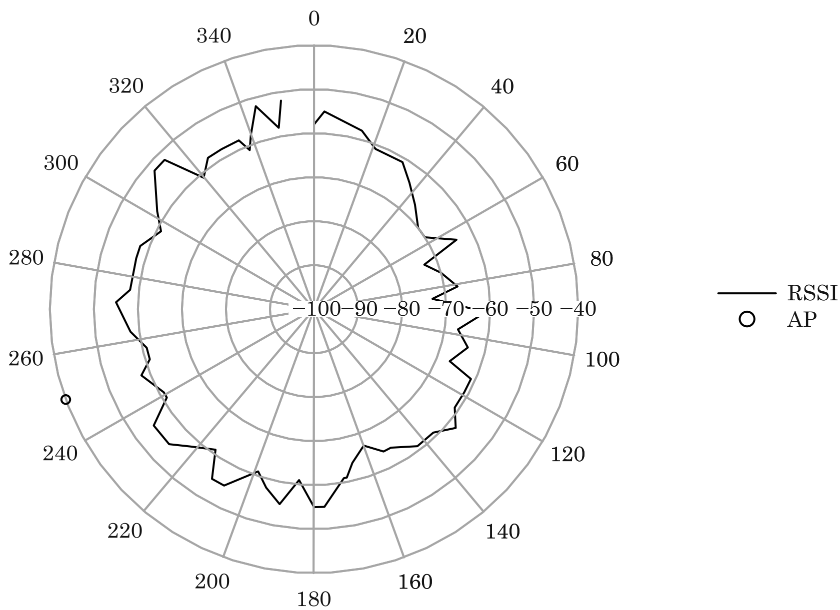

Fig. 8. RSSI [dBm] vs person with smartphone rotation

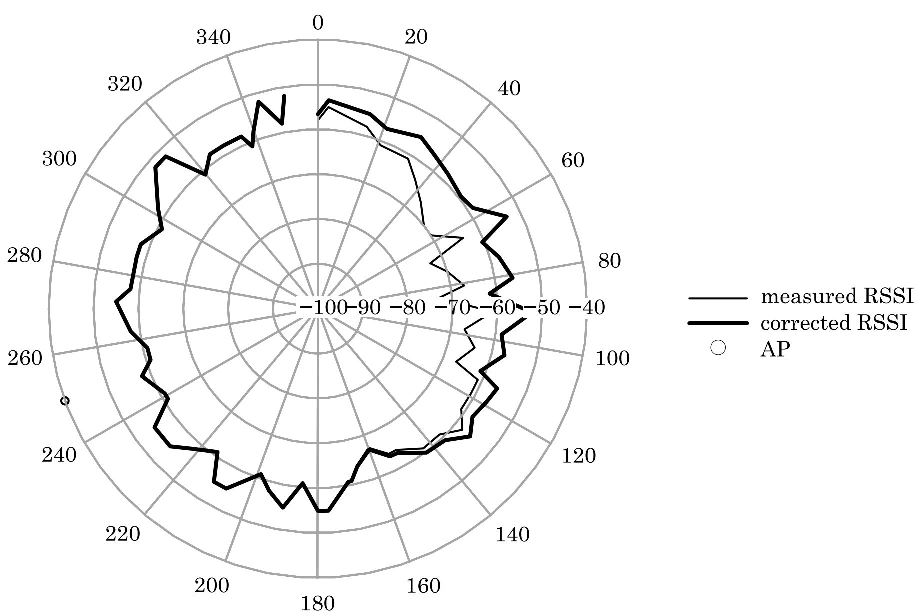

Fig. 9. Results of application of correction function (small room with AP behind the wall $k=6$)

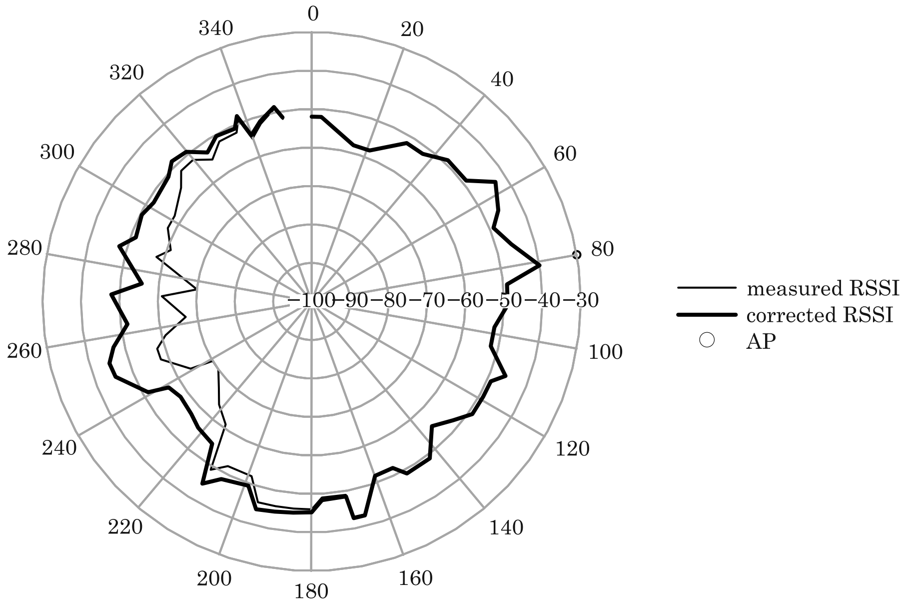

Fig. 10. Results of application of correction function (small room with AP in it k=8)

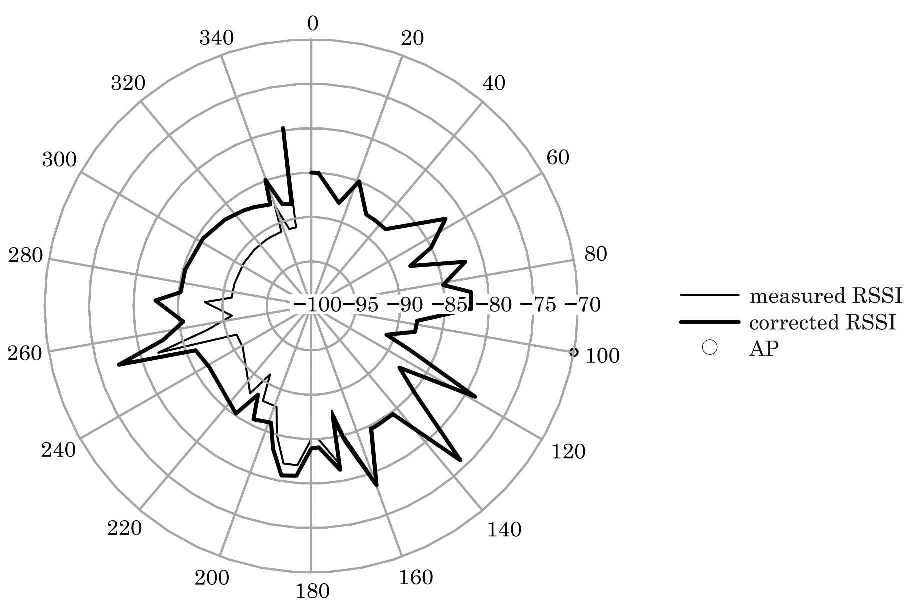

Fig. 11. Results of application of correction function (corridor with AP far from transceiver and behind the wall k=3.5)

The major disadvantage of this approach is that the location of an AP must be known in order to calculate the azimuth. This is only possible when using dedicated infrastructure. In the case when existing infrastructure, with unknown APs location is to be used, a method of finding the location of APs needs to be introduced. This issue will be a topic of further work and papers.

References

BARDWELL J. 2004. *You Believe You Understand What You Think I Said... The Truth About 802.11 Signal And Noise Metrics*. A Discussion Clarifying Often-Misused 802.11 WLAN Terminologies. Technical Report.

CHEFFENA M. 2012. *Physical-statistical channel model for signal effect by moving human bodies*. EURASIP Journal on Wireless Communications and Networking, 2012: 77. DOI: 10.1186/1687-1499-2012-77.

FRIIS H.T. 1946. *A Note on a Simple Transmission Formula*. Proceedings of the IRE, 34(5): 254–256. DOI: 10.1109/JRPROC.1946.234568.

GANSEMER S., GROSSMANN U., HAKOBYAN S. 2010. *RSSI-based euclidean distance algorithm for indoor positioning adapted for the use in dynamically changing WLAN environments and multi-level buildings*. International Conference on Indoor Positioning and Indoor Navigation (IPIN), IEEE, p. 1–6.

IEEE Standards Association. 2012. IEEE Std 802.11TM-2 2012. https://standards.ieee.org/findstds/standard/802.11aa-2012.html.

KUO W.H., CHEN Y.S., JEN G.T., LU T.W. 2010. *An intelligent positioning approach: Rssi-based indoor and outdoor localization scheme in zigbee networks*. International Conference on Machine Learning and Cybernetics (ICMLC), 6: 2754–2759.

SHEN X., WANG Z., JIANG P., LIN R., SUN Y. 2005. *Connectivity and RSSI based localization scheme for wireless sensor networks.* Advances in Intelligent Computing, 3645: 578–587.