Measurement of UHF Signal Strength Propagating from Road Surface with Vehicle Obstruction

C. Thongsopa, P. Sukphongchirakul, A. Intarapanich, and P. Jarataku

Open Science Index, Electronics and Communication Engineering Vol:4, No:9, 2010 publications.waset.org/9147.pdf

Abstract**—**Radio wave propagation on the road surface is a major problem on wireless sensor network for traffic monitoring. In this paper, we compare receiving signal strength on two scenarios 1) an empty road and 2) a road with a vehicle. We investigate the effect of antenna polarization and antenna height to the receiving signal strength. The transmitting antenna is installed on the road surface. The receiving signal is measured 360 degrees around the transmitting antenna with the radius of 2.5 meters. Measurement results show the receiving signal fluctuation around the transmitting antenna in both scenarios. Receiving signal with vertical polarization antenna results in higher signal strength than horizontal polarization antenna. The optimum antenna elevation is 1 meter for both horizon and vertical polarizations with the vehicle on the road. In the empty road, the receiving signal level is unvarying with the elevation when the elevation is greater than 1.5 meters.

Keywords**—**Wave propagation, wireless sensor network.

I. Introduction

THE wireless sensor network is widely used in various applications because of low installation and maintenance cost [1]. In traffic monitoring system, speed, number of vehicles and vehicle types are crucial information. This information can be obtained by processing fundamental data detected by various types of sensor embedded in the sensor node and server node is responsible for processing the data. The wireless sensor network is very attractive for the traffic monitoring system since it provides wireless communication between the sensor node and the server node. Usually, the wireless sensor node is installed on the road surface so that it can detect vehicle. Data from the sensors is then transmitted to a server node via radio channel. However, this radio channel is very complicated since moving vehicles obstruct radio wave propagation from the road surface to the server node [2], [3]. In heavy traffic scenario, the sensor node will be completely blocked by a vehicle for most of the time and, hence, it is very difficult to communicate by radio wave. Moreover, surrounding environment creates multipath propagation. Hence, it is essential to study this radio channel so that the sensor nodes and server node can communicate efficiently.

In this paper, we present signal strength measurements of UHF radio wave. We compare receiving signal strength at the server node for two different scenarios. To study the effect multipath propagation without the effect of vehicle, we perform a measurement on an empty road. In second scenario, the receiving signal strength at the server is observed so that the effect of both environment and vehicle on the radio wave propagation can be investigated. The polarization of the server node antenna is varied to determine the optimum antenna orientation. The server antenna is moved around the sensor node to obtain signal strength in various locations. The effect of antenna height is also investigated by varying the vertical location. In this study, we only consider heavy traffic scenario which is typical for urban area.

This paper is organized by the following. In section II, the details of measurement campaign and system configuration are presented. The measurement results are shown in section III and section IV conclude the paper.

This work was supported by the Research Department Institute of Engineering Suranaree University of Technology Thailand.

C. Thongsopa is with Suranaree University of Technology, Nakhon Ratchasima, Thailand. (e-mail: chan@ sut.ac.th).

P. Sukphongchirakul is with Nakhon Ratchasima Technical College, Nakhon Ratchasima, Thailand. (e-mail: psukpongnum@gmail.com).

A. Intarapanich is with National Electronic and Technology Center, Pathumtani, Thailand. (e-mail: calgalli@gmail.com).

P. Jarataku is with Suranaree University of Technology, Nakhon Ratchasima, Thailand. (e-mail: prapol009@hotmail.com).

II. Wireless Sensor Network Configuration and Measurement Campaign

In this section, we present the detail of wireless sensor network configuration for traffic monitoring system. Then, we show the measurement campaign to obtain the signal strength in various location, height and orientation of the server node antenna.

The wireless sensor network consists of two major parts 1) sensor node and 2) server node. The sensor node is installed on the road surface while the server node can be installed in any location outside the road. The antennas using in both sensor and server nodes are patch type. In this experiment, the transmitter is an Agilent signal generator model E4433B. The center frequency and the modulation are 2.45 GHz and BPSK respectively. The power for transmitting signal is 10 dBm. The receiving signal is acquired by an Agilent N9020A MXA signal analyzer which demodulates the receiving signal into in-phase (I) and Quadrature (Q) components. These I and Q signals are then saved into an internal HDD of the signal analyzer. The capture period is 2 seconds for each measurement. This signal is then analyzed using MATLAB software on a desktop computer. Schematic of the wireless sensor network is shown in Figure 1. The road is 7 meters wide and divided into two lanes which the traffic is running in opposite direction. The server node is located on the road side at the distance of 2.5 meters from the sensor node. The server node is rotated around the sensor node starting from this location which indicates 0 degree of rotation angle. The server node patch antenna is vertically installed on an antenna adjustable pole which controls the antenna height. The actual installation of these equipments is shown in Figure 2.

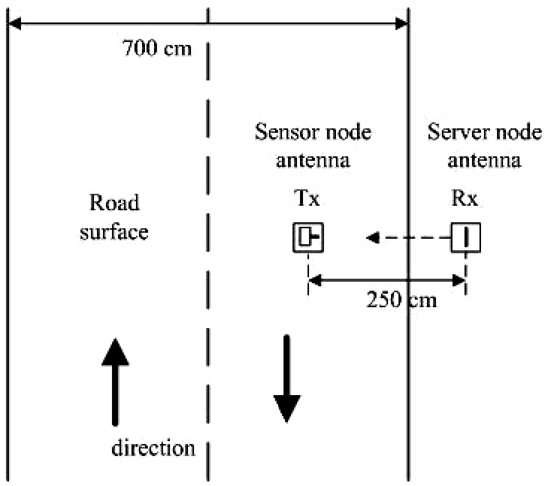

Fig. 1. Schematic of wireless sensor network installation used in this experiment

Fig. 2. Actual installation of the wireless sensor network configuration

The detail of the server node rotation around the sensor node with vehicle obstruction is shown in Figure 3. The server node is rotated clockwise around the sensor node by 10 degrees step until the server node is back to the original location. In each measurement round, the antenna heights at the server node are varied from 0 to 2.5 meter by 0.5 meter step. We first measure the signal strength for the empty road to investigate the effect of surrounding environment to the signal strength at the server node. The second measurement campaign is performed when a pickup truck is parked on the top of sensor node to simulate the heavy traffic scenario in urban area. The bottom of the truck is about 38 centimeters above the road surface. For both empty and non-empty road scenarios, the receiving signal is captured for both vertical and horizontal server antenna polarizations.

The rectangular patch antennas, shown in Figure 4, are used in both server and sensor nodes. The width and height of the patch antenna are 64.39 millimeters and 32.18 millimeters respectively.

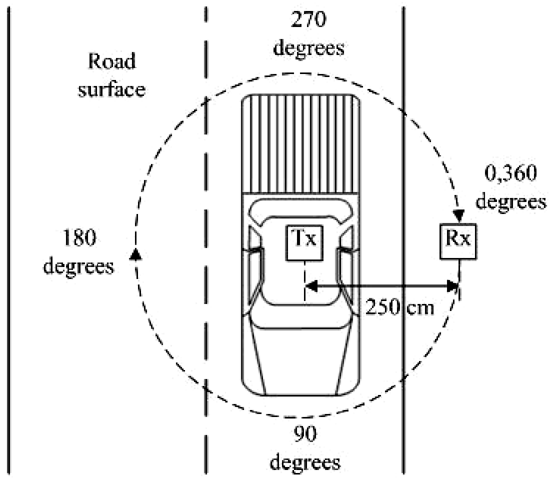

Fig. 3. The detail of measurement campaign with vehicle obstruction

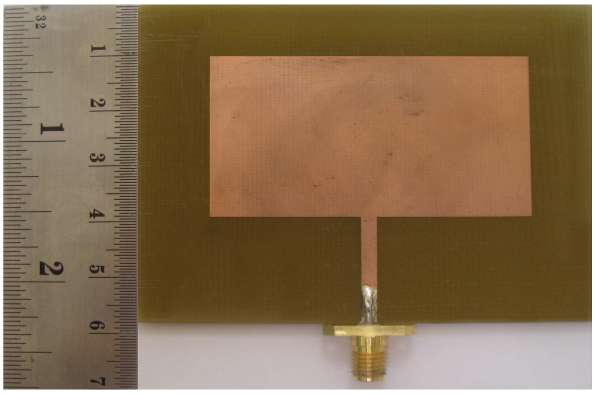

Fig. 4. The patch antenna

III. Measurement Results

We first determine the frequency responds of the patch antenna by using an HP 8722 D network analyzer. The return loss (s_{11}) is -17.289 dB at 2.45 GHz as shown in Figure 5. The radiation pattern of the patch antenna for both H-plane and E-plane are shown in Figure 6.

Open Science Index, Electronics and Communication Engineering Vol:4, No:9, 2010 publications.waset.org/9147.pdf

Open Science Index, Electronics and Communication Engineering Vol:4, No:9, 2010 publications.waset.org/9147.pdf

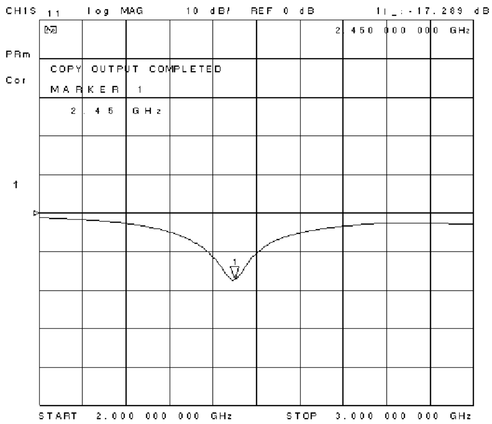

Fig. 5. Return loss (s_{11}) of the patch antenna

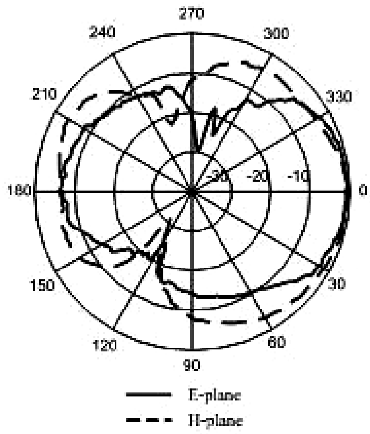

Fig. 6. Normalized radiation pattern of the patch antenna

The receiving signal strengths for both scenarios with vertical and horizontal polarizations are shown in Figure 7 to Figure 12 for the antenna height of 0, 50, 100, 150, 200 and 250 centimeters respectively. When the receiving antenna height is same as the height of sensor node, the signal strength for both scenarios are similar for vertical polarization orientation as shown in Figure 7(a). However, the signal strength for obstructing vehicle with horizontal polarization receiving antenna is lower than the empty road scenario. When the heights of the receiving antenna are 50 and 100 centimeters, the receiving signal strengths are similar for both vertical and horizontal configuration in both scenarios as shown in Figure 8(a)(b) and 9(a)(b). The signal strengths in empty road scenario for horizontal polarization are weaker than vertical polarization for both scenario with the antenna height 50 and 100 centimeters. Figure 10 (a) and (b) show that the receiving signal strength for empty road scenario becomes higher than vehicle obstructing scenario for both vertical and horizontal polarizations when the antenna height is 150 centimeters. When the antenna heights are greater than 150 centimeters, the receiving signal strength for empty road scenario is significantly higher than vehicle obstructing scenario for both polarizations as seen from Figure 11 and 12. It can be seen from Figure 11 and 12 that the signal levels in broadside direction i.e. the angle is 0 and 180 degrees for both scenarios are almost identical.

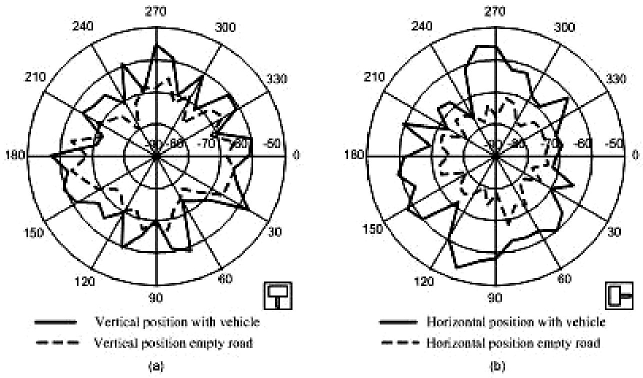

Fig. 7. The comparison received power between empty road and a road vehicle obstruction at server node antenna height of 0 cm (a) vertical and (b) horizontal position

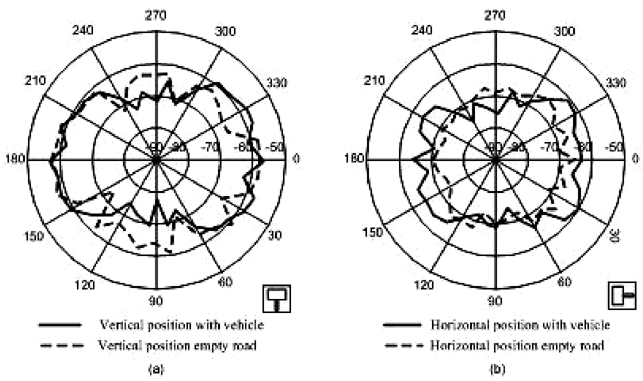

Fig. 8. The comparison received power between empty road and a road vehicle obstuction at server node antenna height of 50 cm (a) vertical and (b) horizontal position

To study the effect of the receiving antenna height to the signal level, the receiving signal strength is averaged over that angle from -45 and 45 degrees for 0 to 2.5 meters height as shown in Figure 13. It can be seen from Figure 13 (a) that the maximum signal level is -54.88 dBm at the height of 1 meter for vehicle obstructing scenario when the receiving antenna is in vertical polarization configuration. When the height is greater than 1 meter, the signal strength drops rapidly for both vertical and horizontal polarizations. In empty road scenario, the receiving signal power directly proportion to the antenna height up to 1.5 meter. When the height is greater than 1.5 meter, the receiving signal strengths do not vary rapidly with the height. In both scenarios, it is clear that the performace of vertical polarization configuration is better than horizontal polarization configuration.

Open Science Index, Electronics and Communication Engineering Vol:4, No:9, 2010 publications.waset.org/9147.pdf

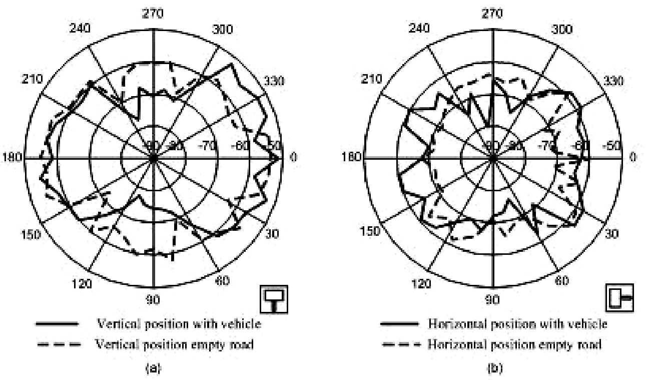

Fig. 9. The comparison received power between empty road and a road vehicle obstruction at server node antenna height of 100 cm (a) vertical and (b) horizontal position

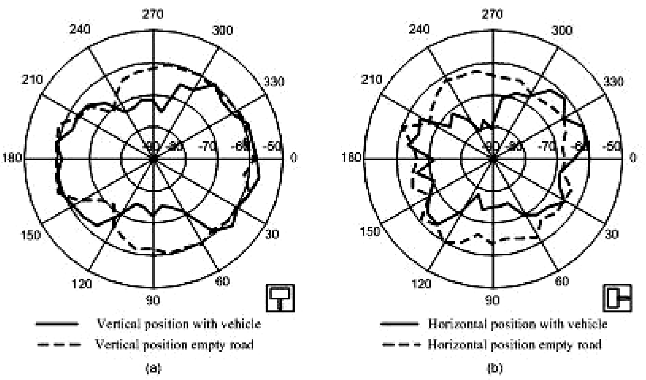

Fig. 10. The comparison received power between empty road and a road vehicle obstruction at server node antenna height of 150 cm (a) vertical and (b) horizontal position

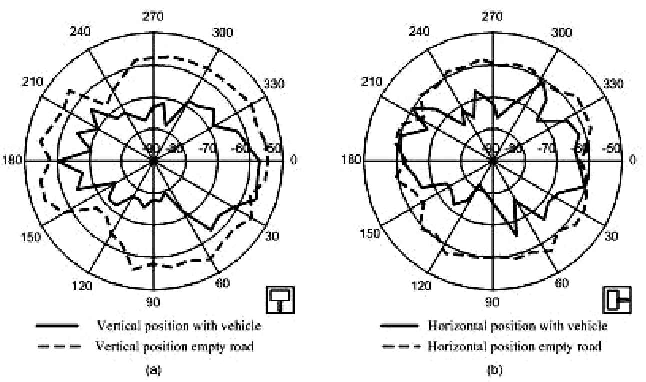

Fig. 11. The comparison received power between empty road and a road vehicle obstruction at server node antenna height of 200 cm (a) vertical and (b) horizontal position

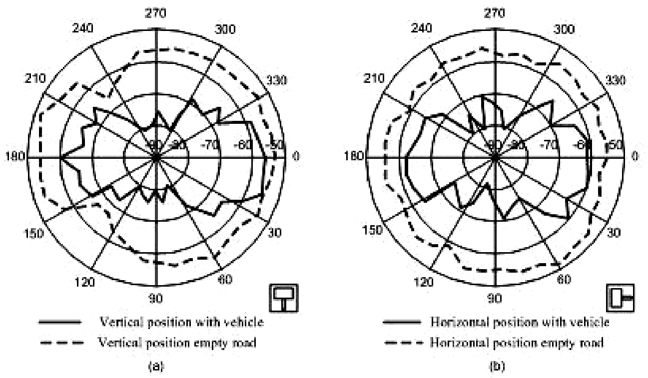

Fig. 12. The comparison received power between empty road and a road vehicle obstruction at server node antenna height of 250 cm (a) vertical and (b) horizontal position

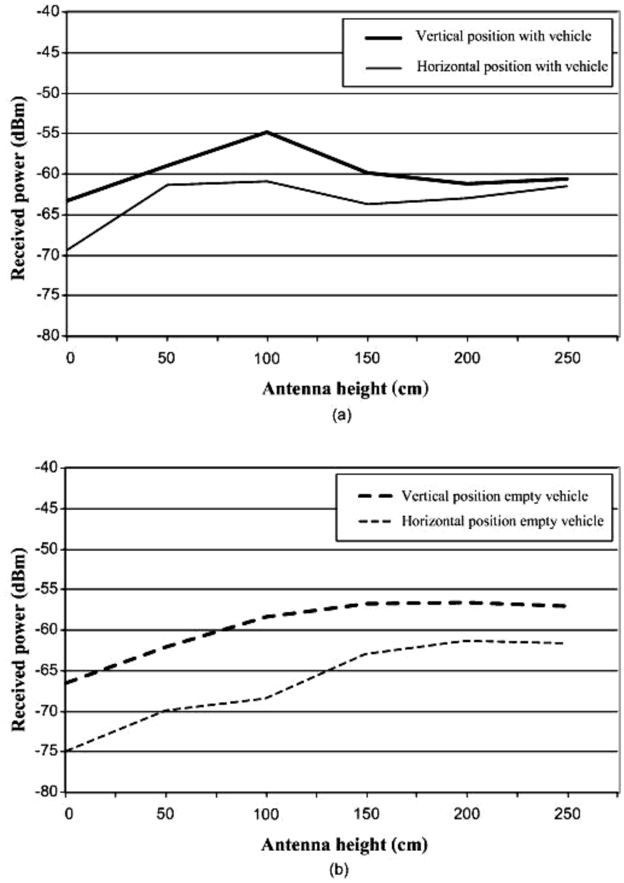

Fig. 13. Received power versus antenna height
(a) vehicle obstructing and (b) empty road scenarios

IV. Conclusion

The measurement results show that the receiving polarization plays a major role in receiving signal strength for wireless sensor network where the sensor node is installed on the road surface. Vertical polarization configuration is suitable for wireless communication with vehicle obstruction. The receiving antenna height is also an important factor to the receiving signal strength. We found that the optimum height is 1 meter for vehicle obstruction scenario. In empty road scenario, there is no benefit of increasing the antenna height greater 1.5 meter.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," *IEEE Communications Magazine*, vol. 40, pp. 102-114, Aug. 2002.

[2] C. Thongsopa, A. Intarapanich, M. Maungrat, "Temporal Measurement of UHF Radio Wave in Presence of Vehicle," *2009 International Symposium on Electromagnetic Compatibility*, July 20-24, 2009.

[3] M. Hadzialic, V.Lipovac, N. Behlilovic, "Fading and Propagation Attenuation Based Explicit Analytical Model for the PDF of Mobile Channel Composite Envelope," *Proceedings of the 18th International Conference, ICECom,* Oct. 12-14, 2005: pp. 1-4 , 2005.

[4] A. Stevens, "Intelligent transport systems, services, solutions, society," *IET Intell. Transp. Syst.*, vol. 1, no. 1, pp. 1-2, Mar 2007.

[5] P. Herley, " Short distance attenuation measurement at 900 MHz and 1.8 GHz using low antenna heights for microcells," *IEEE Journal on Selected Areas in Communications*., vol. 7, no. 1, pp. 5-11, 1989.

[6] M. Rak and P. Pechac, "UHF propagation in caves and subterranean galleries," *IEEE Trans. Antennas Propag*., vol. 55, no. 4, pp. 1134-1138, 2007.

Open Science Index, Electronics and Communication Engineering Vol:4, No:9, 2010 publications.waset.org/9147.pdf