

# Performance Study of Virtual Fence Unit Using Wireless Sensor Network

H.T Chan, T.A Rahman, A. Arsad  
Wireless Communication Centre,  
Universiti Teknologi Malaysia,  
81310 Johor Bahru, Johor, Malaysia  
Telephone: +607 553 6193 Fax: +607 553 5252

**Abstract**—This paper presents the experiments and performance analysis of virtual fence unit consists of microwave motion detector and IEEE 802.15.4 wireless sensor network (WSN) for maximum sensing range. In particular, the analysis is focusing on the maximum sensing range in terms of azimuth angle, height, sensitivity level for indoor and outdoor implementation. The WSN platform is developed using Octopus II sensor nodes while the microwave motion detector is HB100 which detects the movement using Doppler effect. Results show the maximum sensing range of virtual fence unit is decreasing as azimuth angle increasing. With high sensitivity level of virtual fence unit, the maximum sensing range of virtual fence unit is larger than the maximum sensing range of virtual fence unit at normal sensitivity level. Results also show the virtual fence unit has higher maximum sensing range in indoor environment than outdoor environment.

**Keywords**—HB100; Octopus II; virtual fence unit; azimuth; height; indoor; outdoor; maximum sensing range

## I. INTRODUCTION

Infrastructure and site surveillance is imperative with the increasing concern on security and safety. There are two main problems when a conventional fence is used to safe guard a building or a site. Conventional fence has a physical barrier to allow an intruder to hide before breaking into the building or the protected site and there is no notification when an intruder crossed the physical barrier. The problems can be overcome by virtual fencing using wireless sensor network which can detect and localize the intrusion. The role of WSN in border surveillance focuses on information gathering from various types of sensors such as seismic, camera, thermal camera, and motion detectors [1]. Virtual fence system using wireless sensor network is built from a collection of virtual fence unit. In [2], the perimeter of the boundary wall is segmented into

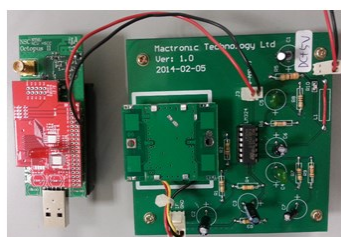


Figure 1. Virtual Fence Unit

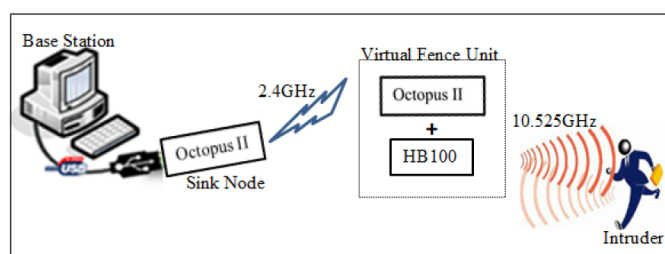


Figure 2. Communication of Virtual Fence Unit

multiple straight-line segments. Each segment is protected against intrusion using a pair of wireless intrusion detection units consists of one infrared sensor unit with both of the infrared receiver and infrared transmitter included a wireless tag to send the intrusion signal wirelessly to control station for alert generation. Virtual fence unit plays an important role in overall performance of virtual fence system using wireless sensor network. It is important to have the long sensing range so that the units of sensor can be minimized. Performance of virtual fence unit may differ in different environment and orientations. Thus, the influence of azimuth angle, height, sensitivity, indoor and outdoor environment on maximum sensing range of virtual fence unit are investigated in this paper. In this paper, virtual fence unit consists of one HB100 motion detector which is a X band (10.525 GHz) sensor utilizes the Doppler effect to detect movement and one Octopus II sensor node which is the wireless communication device with 2.4GHz IEEE 802.15.4 compliant RF. Fig. 1 shows the virtual fence unit in this paper while Fig.2 shows the communications of virtual fence unit in this paper. Magnitude of the Doppler shift of HB100 is in the range of microvolts ( $\mu\text{V}$ ). Amplified Doppler shift is output from the pre amp of HB100 module whenever there is movement detected. 16 samples are taken within a period and then compared with 16 samples taken in previous period. Intrusion notification is sent when the difference between the two samples above a threshold value set. The threshold value represents the sensitivity of the virtual fence unit.

## II. MEASUREMENT CAMPAIGN

A measurement campaign is done within Wireless Communication Centre Universiti Teknologi Malaysia as

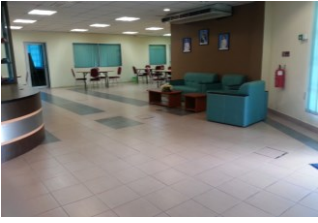


Figure 3. Indoor environment

Figure 4. Outdoor environment

The indoor environment (Fig.3) and rooftop of Wireless Communication Centre Universiti Teknologi Malaysia (Fig.4) as the outdoor environment. The HB100 in virtual fence unit is set at three different heights (30cm, 60cm, and 90cm), 0° to 180° azimuth angle and two different sensitivity levels (normal and high). Throughout the measurement of the maximum sensing range, a person is moving at constant speed at a constant direction until the red LED blinks whenever there is a movement. Distance from the HB100 to the point where the red LED starts blinking is the maximum sensing range in this project. Fig. 5 shows the measurement of maximum sensing range in this project.

### III. RESULTS AND DISCUSSIONS

The measurement results are plotted using radar graph. Fig.6 and Fig.7 show the maximum sensing range at different azimuth angle when the HB100 is set at different height (30cm -blue; 60cm-red; 90cm-green) in indoor and outdoor environment, respectively. To evaluate the performance of virtual fence unit at different azimuth angle, azimuth angle of HB100 is varied by 5° starting from 0° to 180° to get the maximum sensing range. From Fig.6 and Fig.7, the maximum sensing range at each azimuth angle at height 30cm, 60cm and 90cm is found having its peak value at 0° azimuth angle (7.4m in indoor while 4.8m in outdoor). Results show the value of maximum sensing range at each azimuth angle is decreasing as the azimuth angle is increasing. This is due to the Doppler effect is decreasing as the angle is increasing. Eq.(1) shows the formula for Doppler effect [3]. Doppler shift is maximum at 0° azimuth angle but decreases as azimuth angle is increasing. As azimuth angle is increasing, the incident angle is increasing and thus the Doppler shift is decreasing [6]. Since the HB100 detects the movement based on Doppler effect, thus the maximum sensing range is proportional to the Doppler effect.

$$F_d = 2V \left( \frac{F_t}{c} \right) \cos \theta \quad (1)$$

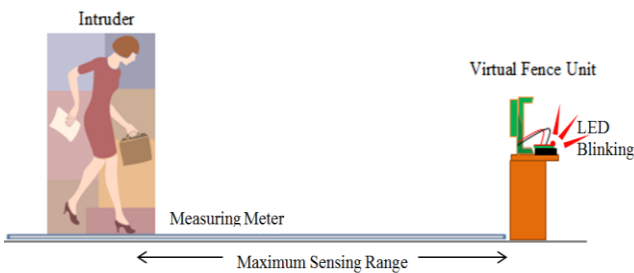


Figure 5. Measurement of maximum sensing range

Where

$F_d$  = Doppler frequency

$V$  = Velocity of the target

$F_t$  = Transmit frequency

$c$  = Speed of light ( $3 \times 10^8$  m/sec)

$\theta$  = The angle between the target moving direction and the axis of the module.

Besides, according to the radiation pattern of patch antenna in HB100 [3] as shown in Fig 12, the radiated energy maximum at 0° azimuth angle and it is decreasing as azimuth angle is increasing. The radiated energy is zero at 180° azimuth angle. When the radiated energy from HB100 is high, the movement can be detected in a longer distance and thus the maximum sensing range is increasing as the radiation energy is increasing and vice versa. This explained the decreasing of maximum sensing range as the azimuth angle is increasing.

From Fig.6 and Fig.7, it is observed that the graph of maximum sensing range at each azimuth angle of HB100 set at height 60cm and 90cm are similar. Thus, an experiment regarding the effect of sensitivity level of virtual fence unit on maximum sensing range at each azimuth angle was carried out. Fig.8 and Fig.9 show the maximum sensing range in indoor environment with HB100 set at height 60cm and height 90cm, respectively while Fig.10 and Fig.11 show the maximum sensing range in outdoor environment with HB100 set at height 60cm and height 90cm, respectively. In Fig.10 to Fig.11, the maximum sensing range at each azimuth angle for high sensitivity and normal sensitivity are indicated in blue and red, respectively.

For indoor environment, increment of maximum sensing range occurred from 0° to 25° azimuth angle with HB100 set at height 60cm and 90cm when the sensitivity of virtual fence unit is high as shown in Fig. 8 and Fig.9, respectively. The increased sensitivity level of virtual fence unit could only affect the maximum sensing range from 0° to 25° azimuth angle at 60cm and 90cm in indoor environment because the antenna patch of HB100 still facing the detection area when it is set from 0° to 25° azimuth angle at which the radiated energy of HB100 still strong. Therefore, the detection range is increased when the sensitivity level of virtual fence is increased.

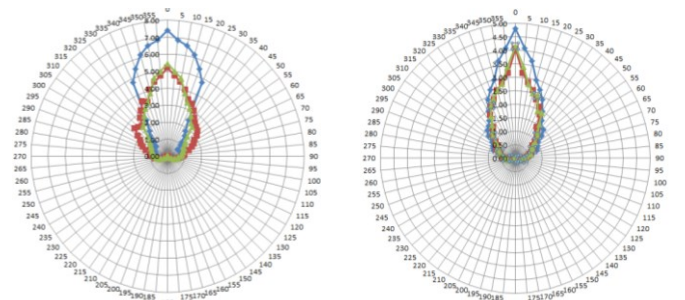


Figure 6. Maximum sensing range at different height in indoor environment

Figure 7. Maximum sensing range at different height in outdoor environment

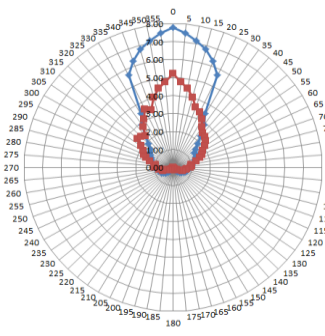


Figure 8. Maximum sensing range at 60cm height with normal sensitivity and high sensitivity in indoor environment

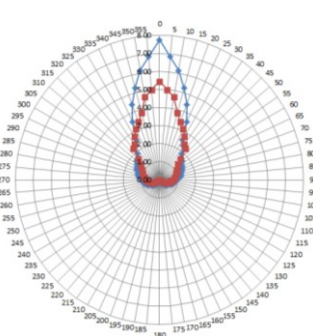


Figure 9. Maximum sensing range at 90cm height with normal sensitivity and high sensitivity in indoor environment

For outdoor environment, it is observed that maximum sensing range of virtual fence unit with high sensitivity level is higher than maximum sensing range at each azimuth angle with the normal sensitivity level at each azimuth angle with HB100 set at 60cm and 90cm as shown in Fig.10 and Fig.11, respectively. However, there is only a little increment on the maximum range at 0 azimuth angle. This indicates the virtual fence unit has reached its maximum sensing range for outdoor environment. The increase of sensitivity level will not further increased the maximum sensing range at 0° azimuth angle. The maximum sensing range of this virtual fence unit at height 60cm and 90cm in outdoor is about 4m in this project.

The significant increase of maximum sensing range at different azimuth angle with HB100 set at 60cm and 90cm in outdoor environment when virtual fence unit is set to high sensitivity level is due to the waving trees which can produce the Doppler shift similar produced by the intruder [5]. As the azimuth angle increases, the area facing the trees increases. Therefore, the maximum sensing range is more easily affected by the waving tree as azimuth angle is increasing and thus increase in maximum sensing range at different azimuth angle when HB100 is set at 60cm and 90cm height in outdoor environment is observed when virtual fence unit is having high sensitivity level. However, this type of motion could cause false alarm [5].

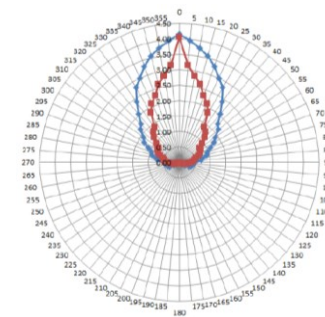


Figure 10. Maximum sensing range at 60cm height with normal sensitivity and high sensitivity in outdoor environment

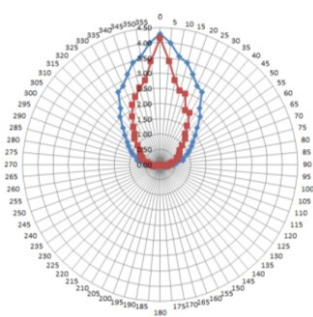


Figure 11. Maximum sensing range at 90cm height with normal sensitivity and high sensitivity in outdoor environment

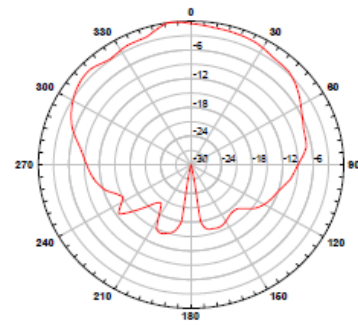


Figure 12. Radiation Pattern of HB100 in Azimuth

Results also show that the maximum sensing range of virtual fence unit set at different height, azimuth angle and sensitivity level in indoor environment is better than outdoor environment. Virtual fence unit can detect movement in longer range at different azimuth angle when HB100 is set at different height and at different sensitivity level in indoor environment than outdoor environment. Based on the above observations, the virtual fence behaves differently in indoor and outdoor environment, thus it is agreed that virtual fencing unit using microwave motion detector for indoor environment could not be used in outdoor environment as mentioned in [5]. Indoor units can recognize a Doppler shift produced by a moving target to detect intruders while the waving trees in outdoor could produce the Doppler shift similar to those produced by the intruder which will then cause the false alarm [5].

#### IV. FUTURE WORKS

In the future, the angle of HB100 can be set using step motor to avoid the parallax error and thus increase the accuracy of angle measurement. Virtual fence unit can be combined with PIR sensor to make sure the intrusion detected is from human. By using dual sensor, false alarm can be reduced because intruder notification will only be sent if both microwave sensor and PIR sensor detect the intrusion. In addition, camera will be installed around the perimeter of WCC UTM building to capture the intruder. Lastly, a virtual fence system will be setup around the perimeter of WCC UTM building using a collection of virtual fence unit which will detect, localize and capture the picture of the intruder then send the intruder notification to the monitoring room.

#### V. CONCLUSION

Influence of azimuth angle, height, sensitivity level, indoor and outdoor environment on the maximum sensing range of virtual fence unit has been investigated. It is found that virtual fence unit can detect movement in longer distance when it is at 0° azimuth angle, at 30cm height and in indoor environment. Maximum sensing range will not be affected by increased sensitivity level if it is already at its maximum value. This paper also shows that virtual fence indoor system using microwave motion detector for indoor environment could not be used in outdoor environment as mentioned in [5].

## ACKNOWLEDGMENT

The authors would like to acknowledge and express sincere appreciation to Universiti Teknologi Malaysia and Wireless Communication Centre for financing this project.

## REFERENCES

- [1] Emad Felemban, "Advanced Border Intrusion Detection and Surveillance Using Wireless Sensor Network Technology," Int. J. Communications, Network and System Sciences, 2013, 6, 251-259
- [2] Prashant Kharat and Jayashree Kharat, "Wireless Intrusion Detection System Using Wireless Sensor Network: A Conceptual Framework," International Journal of Electronics and Electrical Engineering Vol. 2, No. 2, June, 2014
- [3] HB100\_Microwave\_Sensor\_Application\_Note, [http://www.limpkin.fr/public/HB100/HB100\\_Microwave\\_Sensor\\_Application\\_Note.pdf](http://www.limpkin.fr/public/HB100/HB100_Microwave_Sensor_Application_Note.pdf)
- [4] Octopus II, SUREWIN Technology CO., Ltd.
- [5] Robert L. Barnard, Intrusion Detection Systems, 2nd ed., pp.167-175
- [6] Vinay Negi, Sanjeev Kumar Shah, Sandeep Singh and Arun Shekhar. Equalization of Doppler Effect Using Constellation Diagram of 8-PSK Modulation. International Journal Of Computational Engineering Research (ijceronline.com). 2013. 3(3):203- 208