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Study of Obstacles Effect on Mobile Network and WLAN Signal Strength

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***Abstract*—In the era of continuous advancement in wireless technologies, path loss, also known as channel attenuation, is a drop in signal strength from the transmitter to the receiver. Path loss modelling is critical in designing fixed and mobile communication systems for various applications. This paper focuses on the received power (dBm) and free space path loss (FSPL) on various distances and frequencies such as 5240 MHz for wireless local area network (WLAN) and frequency such as 2100 MHz for the mobile network such as Celcom. As a result, able to analyze the correspondence between received power (dBm) and distance of each related frequency and the correspondence between FSPL (dB) and distance of each corresponding frequency and able to analyze the effect of obstacle on received power (dBm) and frequency.**

***Keywords*— free space path loss (FSPL), mobile network, received power (dBm), WLAN**

I. INTRODUCTION

AN electromagnetic component of a wireless communication system acts as a link between the transmitter and receiver and their surroundings, known as an antenna [1]. Additionally, electromagnetic propagation's effect on the external environment is a critical component of the electromagnetic system, and it often plays a significant role in system design as well as antenna component selection; it is also important to consider the frequency of electromagnetic waves that are transmitted between two locations [1] - [2]. As the signal propagates from the transmitter to the receiver, it loses signal strength, causing phase and amplitude fluctuations [3]. In radio communication systems, the propagation path loss is the loss that happens between the transmitter and the receiver [3].

WLAN refers to a wireless distribution technique that links one or more wireless devices [4]. By using WLAN, the access point is a part of a more extensive network [5]. WLAN can move around a local area network using this technique, utilizing the internet's resources. Local area networks (LANs) rely heavily on wireless networks [6]. Using 2.4 GHz or 5 GHz radio waves, WLANs often act as an access point of a wireless network [7]. As long as the network connection is maintained, users can access the internet inside the wireless network coverage area, which is typically a living room or office [8]. In the absence of Wi-Fi connectivity, smartphones can connect to the internet using mobile data transmitted via a cellular carrier [9]. Often network providers provide telephone or internet services to the network subscriber send and receive text messages, make and receive phone calls, watch a video, social media update, or browse the internet [9]. Mobile data usage is not affected by phone calls or texts sent or received [9].

This paper focuses on the received power (dBm) and free space path loss (FSPL) on various distances and various frequencies such as 5240 MHz for wireless local area network (WLAN) and frequency such as 2100 MHz for the mobile network such as Celcom 4G LTE. Also, to analyze the correspondence between received power (dBm) and distance of each related frequency and the correspondence between FSPL (dB) and distance of each related frequency and able to analyze the effect of obstacle on received power (dBm) and frequency.

II. THEORY

A. Friss Transmission Equation

Received power stands for the received signal level, which is the signal strength obtained by the smartphone from a cell tower antenna [10]. It is importing factor that determines that the reception was good or not [11]. The received power (dBm) can be measured as Reference Signal Received Power (RSRP) for Mobile network 4G LTE and as Received Signal Strength Indicator (RSSI) [12]. The level ranges for RSRP and RSSI, and its rating as shown in Table I and Table II, respectively. RSSI is read-out in dBm returned by the receiver [13]. The mathematical formula to calculate the received power (dBm) by using the Friis transmission equation is given as:

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

and the value of P_r in unit Watts can be converted to the unit dBm using:

$$P_r\left(\text{dBm}\right) = 10\log_{10}\left\{P_r\left(\text{Watts}\right)\right\} + 30 \tag{2}$$

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where P_r and P_t are the received power and transmitted power at receiving antenna and transmitting antenna, respectively. On the other hand, G_r and G_t are the gain (dimensionless) of the receiving antenna and transmitting, respectively. Symbols λ and d are the operating wavelength and separation distance between the receiving and transmitting antennas.

TABLE I
RSRP RANGES AND RATING [11]

RSRP Ranges (dBm)	Rating
-47 dBm to -10 dBm	Very good
-60 dBm to -47 dBm	Good
-75 dBm to -60 dBm	Better range of coverage
-90 dBm to -75 dBm	Average coverage
-95 dBm to -90 dBm	Poor coverage
-110 dBm to -95 dBm	Very bad coverage

TABLE II
RSSI RANGES AND RATING [14]

RSSI Ranges (dBm)	Rating
> -65 dBm	Excellent
-65 dBm to -75 dBm	Good
-75 dBm to -85 dBm	Fair
-85 dBm to -95 dBm	Poor
<= -95 dBm	No signal

B. Free-Space Path Loss (FSPL)

The free-space path loss (FSPL) is used to calculate the attenuation between two points based on a clear line of sight [15]. The main attenuation formula for electromagnetic signals in free space is given by Equation (1), the FSPL which can be derived from the Friis transmission equation by the condition of $G_t = G_r = 1$ [16] - [17]. From equation (3), it is shown the effect of frequency and distance, d on the path loss for different frequencies [16].

$$\text{FSPL}(\text{dB}) = 20\log_{10}\left(\frac{4\pi d f}{c}\right) \tag{3}$$

where f and c (= 299792458 m/s) are the operating frequency in unit Hz and the speed of light in free space.

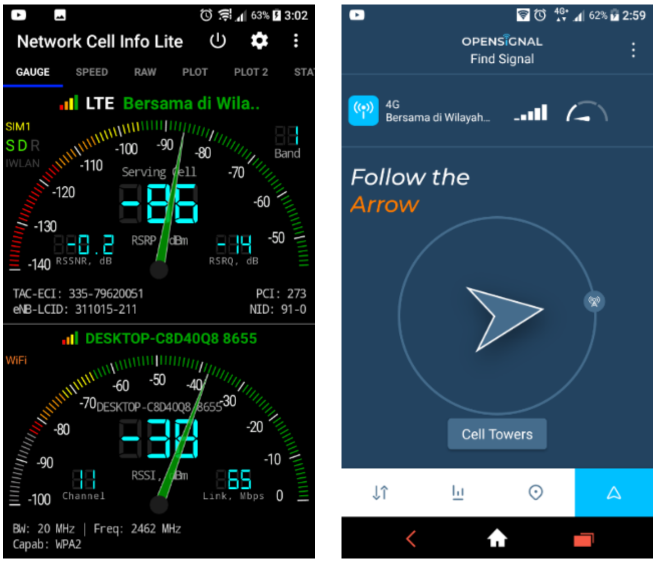
III. EXPERIMENTAL

In this paper, the study used two mediums: mobile network and wireless local area network (WLAN). The mobile network used is Celcom 4G, which operates at 2100 MHz (B1) [18], while the WLAN used is UniMAP-WIFI, which operates at 5 GHz. The measurement of mobile network, WLAN, and obstacle setup was conducted in the Unicity Alam at Padang Besar, Perlis.

A. Experimental

1) Network Cell Info Lite & Opensignal Apps

As shown in Fig. 1a, Network cell info lite is a smartphone application. It is a comprehensive mobile network/WIFI monitor and a measurement/diagnostic log tool that helps to troubleshoot reception and connectivity issues [19]. Besides that, used to obtain pieces of information such as received signal strength indicator (RSSI), reference signal received power (RSRP), and the LTE frequency band of the mobile network, as shown in Fig. 1a. Opensignal application has a function of cell tower compass, which indicates the direction the closest or strongest signal is coming from, as shown in Fig. 1b [20]. Also, it shows the visual of the connected or nearby tower and lists out the cell ID [21]. In Fig. 2, an access point that uses an ethernet connection to connect to a wired router, switch, or hub and broadcasts the UniMAP-WIFI signal to a UniMAP campus area [22].



(a) (b)

Fig. 1. (a) The interface of the Network Cell Info, (b) Shows connected and nearby tower

2) Access Point of the UniMAP-WIFI

Fig. 2. Access point of the UniMAP-WIFI

An access point is created by using the hotspot feature of a smartphone which is used in the obstacle measurement setup [23]. Fig. 3 shows the smartphones used as an access point as transmitter via the hotspot function, and the smartphone connected to the access point act as a receiver. A cellular firm constructs cell towers to increase cellular network coverage or capacity, resulting in a stronger reception signal in that regional area [22]. The location of the tower is determined by using the Opensignal application, as shown in Fig. 4.

3) Access Point of the Smartphone

(a) (b)

Fig. 3. (a) Smartphone as an access point (b) Smartphone as receiver

4) Celcom Cellular Network Tower

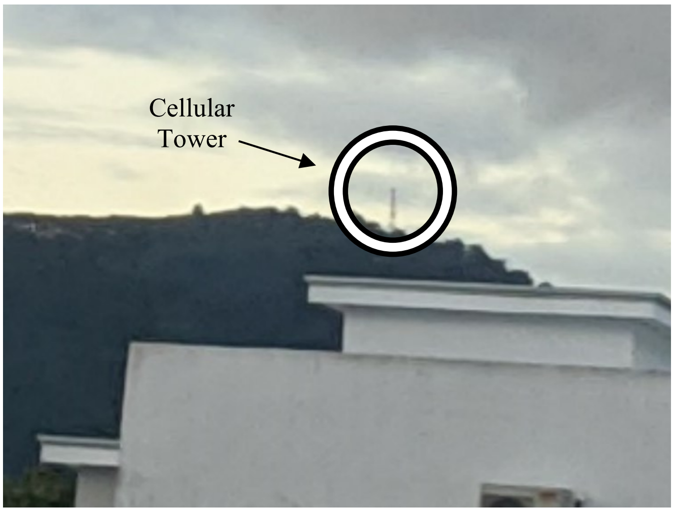


Fig. 4. Celcom cellular tower

IV. TYPE OF MEASUREMENT SETUP

A. Mobile Network

The measurement setup for the mobile network is set with the functionality of the Opensignal and google maps application, which is used to determine the connected cellular tower to the smartphone and the actual distance between two points of the measurement setup. This measurement setup has four different distances to measure the smartphone's Reference Signal Received Power (RSRP) using 4G Celcom mobile network, as shown in Fig. 5.

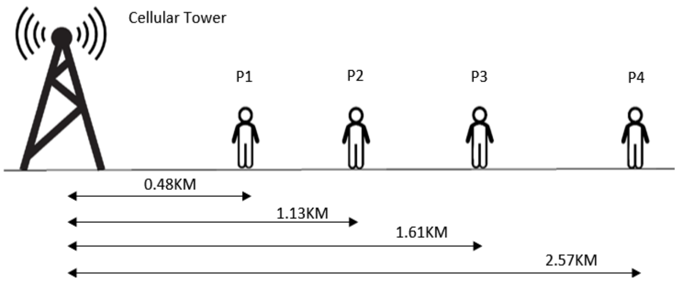


Fig. 5. The measurement setup of mobile network

B. WLAN

The measurement setup for the mobile network is set with the Google Maps application's functionality, which determines the actual distance between two points of the measurement setup. This measurement setup has five different distances to measure the Received Signal Strength Indicator (RSSI) of the smartphone by using the access point of UniMAP-WIFI, as shown in Fig. 6.

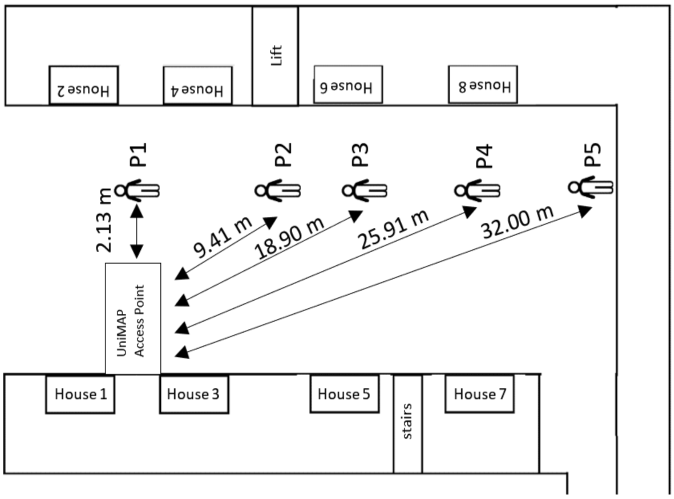


Fig. 6. The measurement setup of the WLAN

C. Obstacle

The obstacle can be anything that can block or reduce the received power in the terms of Received Signal Strength Indicator (RSSI). There are four measurement setups for obstacles such as plywood door, human, single wall, and multiple walls.

1) Plywood Door

As shown in Fig. 7 and Fig. 8, the measurement setup is done by using two smartphones, where the smartphone (transmitter) is 1.8 m in front of the plywood door that uses a mobile network hotspot is turned on. Another smartphone (receiver) is 1.8 m behind the plywood door (obstacle), is connected to the hosted hotspot, and measures the received power (dBm) in the Received Signal Strength Indicator (RSSI) at the network cell info lite application. The reading is taken for opened and closed plywood doors to analyze the received power (dBm).

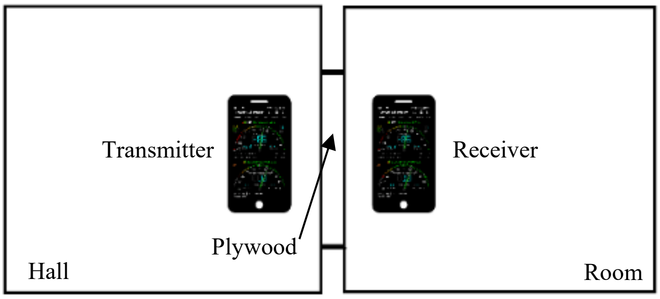


Fig. 7. The measurement setup for closed plywood door as an obstacle

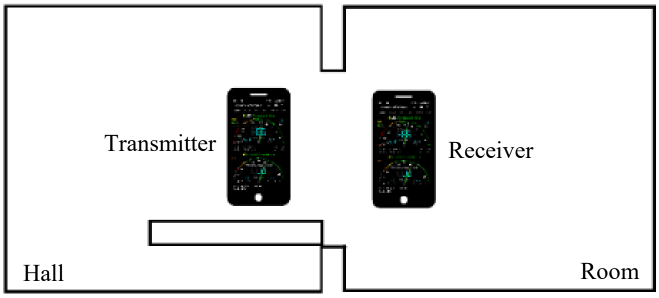


Fig. 8. The measurement setup for opened plywood door without an obstacle

2) Human

As shown in Fig. 9, the measurement setup is done by using two smartphones, where the smartphone (transmitter) is 1.8 m in front of the human (obstacle) that uses a mobile network, and the hotspot is turned on. Another smartphone (receiver) set 1.8 m at the behind of the human is connected to the hosted hotspot and measure the received power (dBm) in the Received Signal Strength Indicator (RSSI) at the network cell info lite application.

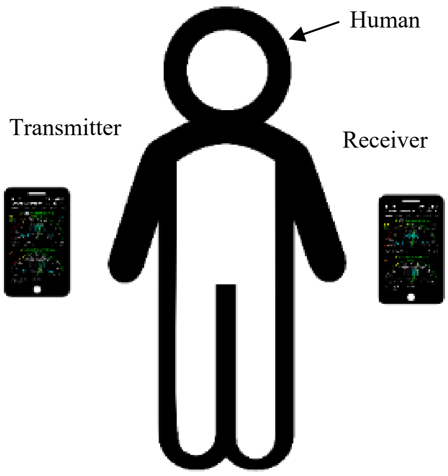


Fig. 9. The measurement setup for the human as an obstacle

3) Single Wall

As shown in Fig. 10, the measurement setup is done by using two smartphones, where the smartphone (transmitter) is set up 1.8 m away from the wall in room 1. Another smartphone (receiver) is set up 1.8 m away from the wall at room 2 to measure the received power (dBm) in Received Signal Strength Indicator (RSSI) at the network cell info lite application.

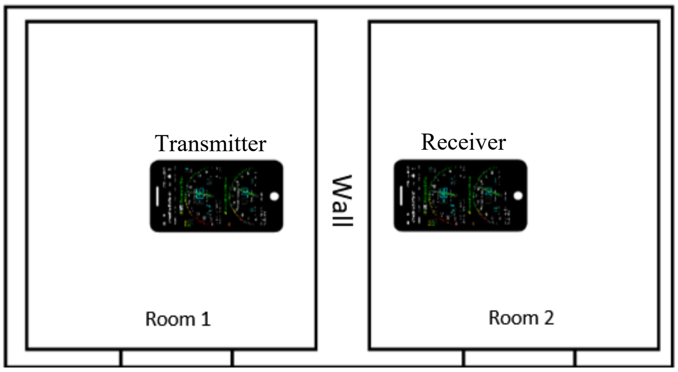


Fig. 10. The measurement setup for the single wall as an obstacle

4) Multiple Wall

As shown in Fig. 11, the measurement setup is done by setting one of the smartphones (transmitter) 1.8 m away from a wall at the hall. Another smartphone (receiver) is set 1.8 m away from a wall at room 2 to measure the received power (dBm) in Received Signal Strength Indicator (RSSI) at the network cell info lite application.

Fig. 11. The measurement setup for the multiple walls as an obstacle

V. RESULTS AND DISCUSSION

A. Received Power

1) Mobile Network

The smartphone's cellular network has been connected to a nearby 4G LTE Celcom cellular network tower; the assigned LTE band is 1, which is 2100 MHz. As shown in Fig. 12, at the of 0.48 km away from the Celcom tower, the received power in RSRP is -79 dBm which the signal strength is receivable, stable, and has good coverage despite obstacles in the path of transmission. When the distance is increased from the Celcom tower to 1.13 km, the received power is decreased to -91 dBm due to distance and obstacles. On the other hand, when the distance further increased from the Celcom tower to 1.61 km and 2.57 km, the received power is -100 dBm and -119 dBm, respectively; both received power is lower than the previously measured value due to long-distance, buildings, vegetation, and the terrain. As the distance away from the Celcom tower increases, the received power decreases. Therefore, the signal strength of the tower fades away as the distance increases, as shown in Fig. 13.

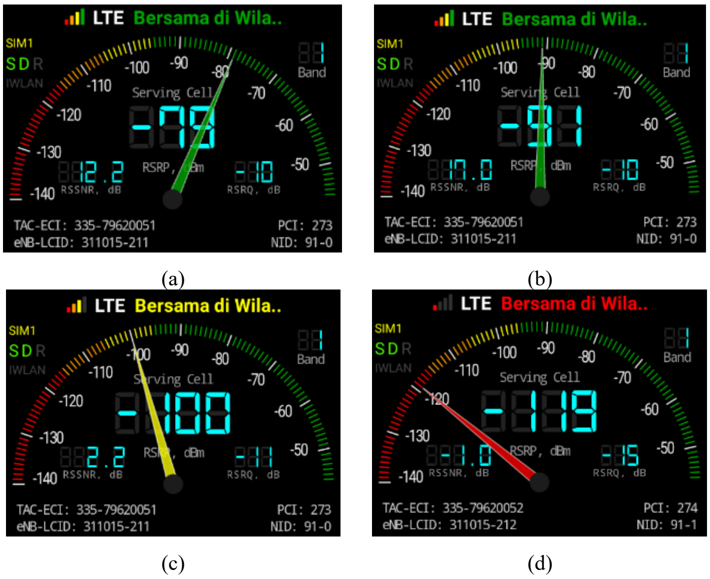


Fig. 12. (a) 0.48 km, (b) 1.13 km, (c) 1.61 km, (d) 2.57 km

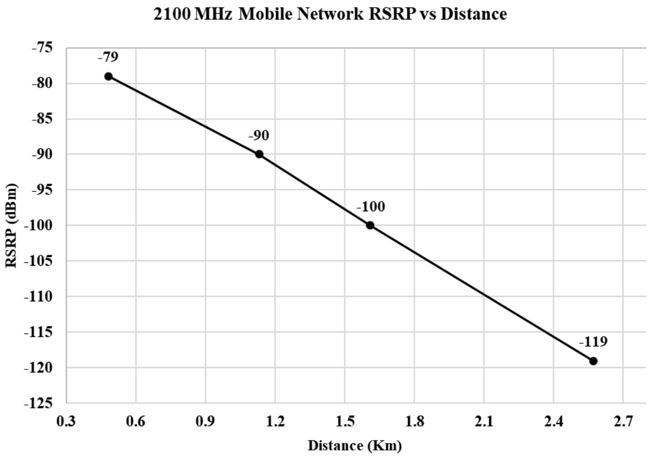


Fig. 13. The result of 2100 MHz mobile network received power vs distance.

2) WLAN

The smartphone's wireless network connected to the nearby WIFI access point that is UniMAP-WIFI, which has two frequencies but tested want is the frequency band of 5240 MHz. By referring to Fig. 14, at 2.13 meters away from the UniMAP-WIFI access point (AP), the received power in RSSI is -34 dBm. The signal strength is stable and has excellent coverage due to no obstacle. When the distance away from the AP to 9.14 meter, the received power in RSSI is at -54 dBm, which decreases in signal strength due to distance. On the other hand, when the distance further away from the AP to 18.9 meters and 25.91 meters, the received power is -61 dBm and -67 dBm, respectively, also decreases signal strength. As the distance away from the access point increases, the received power decreases. Therefore, the access point's signal strength fades away as the distance increases, as shown in Fig. 15.

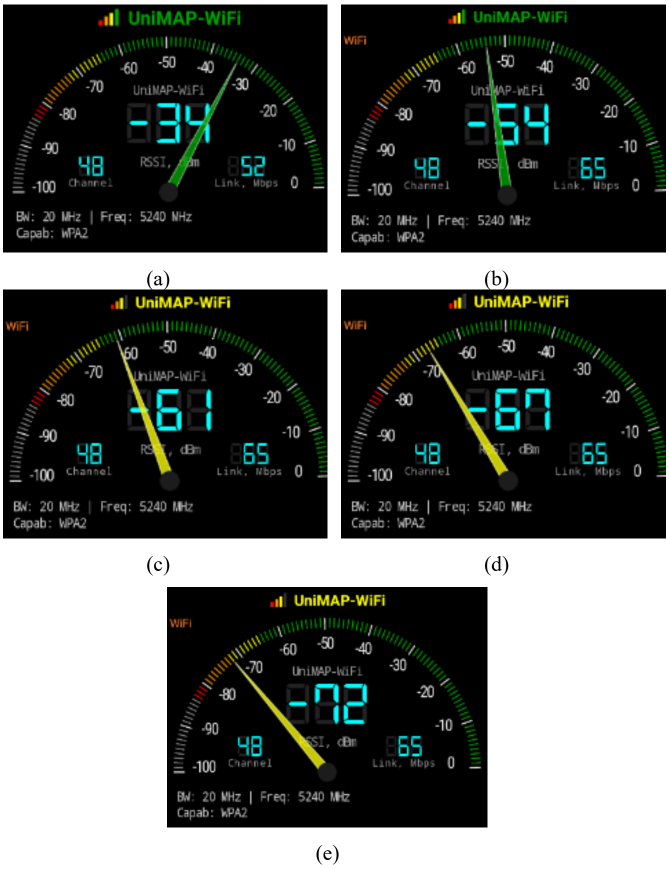


Fig. 14. (a) 2.13 m, (b) 9.14 m, (c) 18.9 m, (d) 25.91 m, (e) 32 m

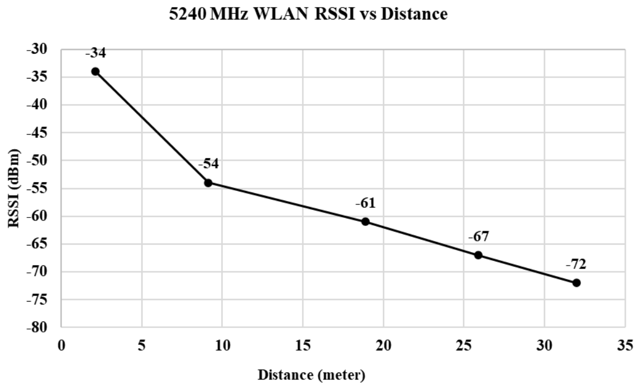


Fig. 15. The result of 5240 MHz WLAN received power vs distance.

B. Free Space Path Loss (FSPL)

1) Mobile Network

The FSPL is obtained using the equation(4) for the smartphone connected to a 4G LTE Celcom cellular network tower. By referring to Fig. 16, the value of FSPL is increasing as the distance increase because 4G LTE Celcom cellular network tower losses in signal strength as distance increases. Also, the line of sight (LOS) through free space will have some obstacles nearby to cause reflection, diffraction, or absorption losses.

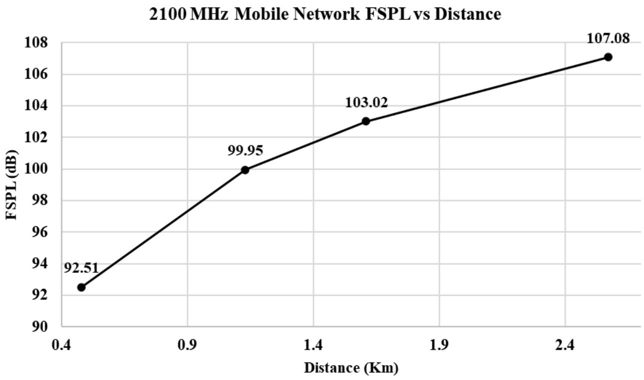


Fig. 16. The result of 2100 MHz mobile network FSPL vs distance

2) WLAN

The FSPL is obtained using the formula of (3) for the access point of the UniMAP-WIFI. By referring to Fig. 17, the value of the FSPL increases as the distance increase because the AP has a loss in signal strength if the connected devices are further away and with no obstacles nearby to cause reflection or diffraction.

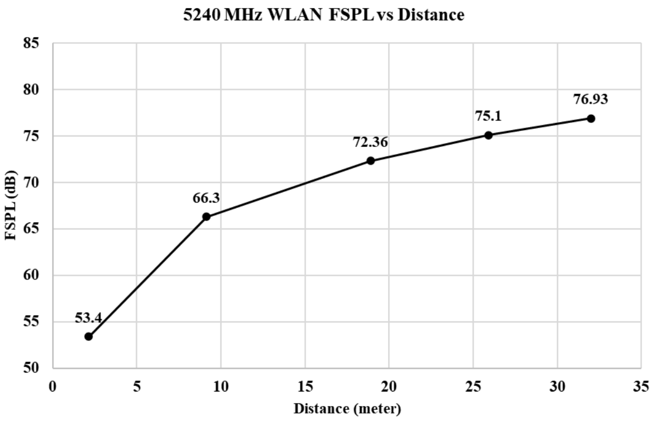
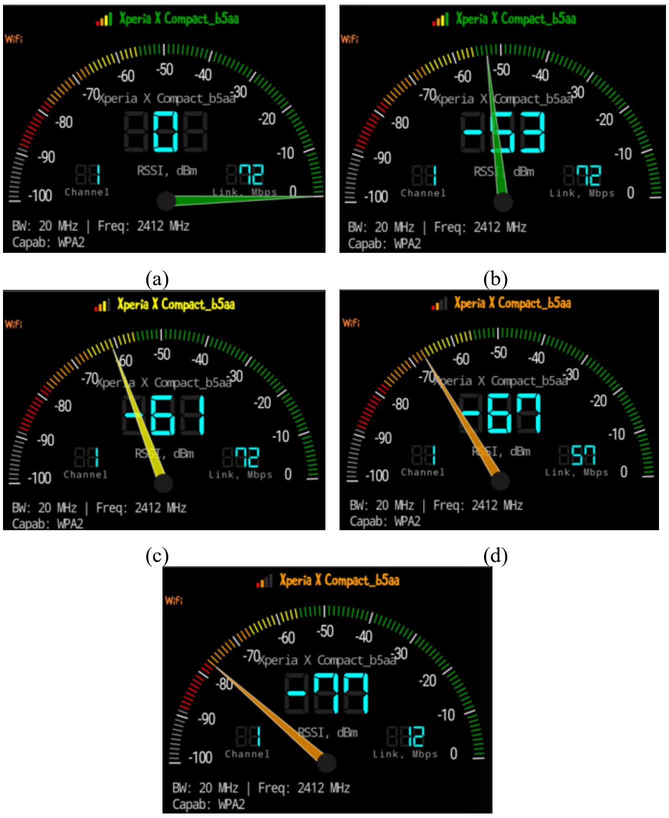


Fig. 17. The result of 5240 MHz WLAN FSPL vs distance.

C. Obstacles

By referring to Fig. 18, various obstacle testing was conducted to measure the signal strength in RSSI of the hotspot that was set up at a frequency of 2412 MHz. For initial reading taken as no obstacles between smartphones, the signal strength in RSSI is 0 dBm. For the Plywood Door as an obstacle, the signal strength in RSSI is -53 dBm, which shows that the surrounding area has excellent coverage due to the plywood door being a less dense obstacle. The signal strength is -61 dBm for humans as obstacles, as humans are denser than plywood. Besides that, the signal strength is -67 dBm for a single wall, which is slightly less than human as obstacles. For the multiple walls, the signal strength is -77 dBm as various obstacles and distance play the factor for low RSSI value.



(e)

Fig. 18. (a) No Obstacles, (b) Plywood Door, (c) Human, (d) Single Wall, (e) Multiple Wall

CONCLUSION

The primary objective of this paper is to analyze the received power (dBm) and free space path loss (FSPL) at 5240 MHz for WLAN and at 2100 MHz for the mobile network. As a result, able to analyze the correspondence between received power (dBm) and distance of each related frequency and the correspondence between FSPL (dB) and distance of each related frequency. As the distance increases, the value of the FSPL increases, this cause the power receives decreases. This study also present the effect of obstacle and frequency on received power (dBm). The results show the denser obstacle, the more signal attenuated andindicate lower power receivedsignal strength, such as multiple walls record the lowest power receive among other obstacles.

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