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2.4 GHz Omnidirectional Antenna Design with Microstrip Technologies for GSM to Internet Protocol Repeater

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Abstract— *Unavailability (Blank Spot) signal in a particular area is a threat to the rapid development of telecommunications today. By using Omnidirectional Antenna design with Micro-strip technology, this research aims to build a signal repeater system that does not violate the rules of government rules. The antenna in this study was designed using CST Studio software. the antenna will work on channel frequency 2.4 GHz - 2.49 GHz with the gain position in 2 dBi, after design and simulation by using the software done then continue to fabrication using FR4 material with 1.6mm thickness. Trial omnidirectional antennas under real conditions after fabrication successfully transmit signals as far as 200m with standard routers.*

Keywords— *Antenna, Omnidirectional, Mikrostrip, Repeater.*

I. Introduction

The rapid development of mobile communications technology in the past decade has greatly improved with many providers offering a wide range of mobile telecommunication services. Users or consumers of mobile communications are also given the convenience to get a communication device with various brands and types of prices tend to be relatively cheap.

The problems accompanying the development of mobile telecommunications is the inadequate availability of signals in some areas that cause uneven effects on the development of mobile telecommunications technology. BTS which is assigned as the repeater of cellular signal (Repeater) has limited coverage area, the other issuance of ban *GSM signal amplifier* by the government of Indonesia make the way out for limitations of a coverage area of cellular signal become more hampered. To solve the problem of limitation signals owned by GSM devices that rely on base stations as signal signals (Signal Repeater), in this study is to change the GSM system used to be Internet Protocol based.

By using internet service from GSM providers, GSM signals will be converted to internet protocol based which can then be retransmitted through Wireless Access Point device with working frequency 2.4 GHz where the frequency is far above the other frequency band used so as not to interfere with communication and more important not to violate the rules of the Indonesian government.

Micro-strip antennas are widely developed to support Broadband Wireless Access (BWA) technology. BWA is an access technology that can offer high-speed data/internet access and is capable of providing services anytime and anywhere using wireless media. In Indonesia, the arrangement of radio frequency bands for BWA purposes has been stipulated in MENKOMINFO Regulation No. 07 / PER / M.KOMINFO / 01/2009 that is using the band 300 MHz, 1.5 GHz, 2 GHz, 2.3 GHz, 3, 3 GHz and 10.5 GHz. The frequency of use permission is based on radio frequency band license. As for the 2.4 GHz and 5.8 GHz frequency bands, the permission to use their frequency is based on class permission [xxx].

The purpose of this research is to design the conversion system and the repeater (repeater) in the form of antenna with micro-strip type with omnidirectional signal pattern with 2.4 GHz frequency channel, so it can be implemented into the transmitter system for GSM signal converter into internet protocol and it can be useful to help areas that still have difficulty communicating using GSM network can be replaced using internet protocol so that people can do internet-based communication. According to Warren L. Stutzman and Gary A. Thiele that the antenna must at least meet 2 standard criteria in order to work maximally, i.e. the value of SWR (Standing Wave Ratio) whose value must be < 2 and the channel impedance value with antenna impedance match its value should be close to 50Ω [xxx].

II. Research Methodology

This research methodology flow as shown in Figure 1 show the first step is to conduct a literature study for looking knowledge sources of reference either in the form of books or journals in the form of internet media related to research conducted. Literature collected about cellular telecommunication technology and about antenna, especially with micro-strip type. The next step is to determine the antenna specification that will be designed, the antenna will be made to transmitting the signal to all directions (omnidirectional) with the frequency of work at 2.4 GHz and the gain position more than or equal 2 dBi. In this research, software CST Studio using for design the antenna and do simulation for the design. If the simulation results do not conform to the specifications specified in the beginning, then there is a need for correction of each component and all its entities. If the simulation results have been in accordance with the specified specification that the value of VSWR is close to nominal 1 and radiation pattern is appropriate then the antenna is ready to be designed. Below is flow-chart of research methodology

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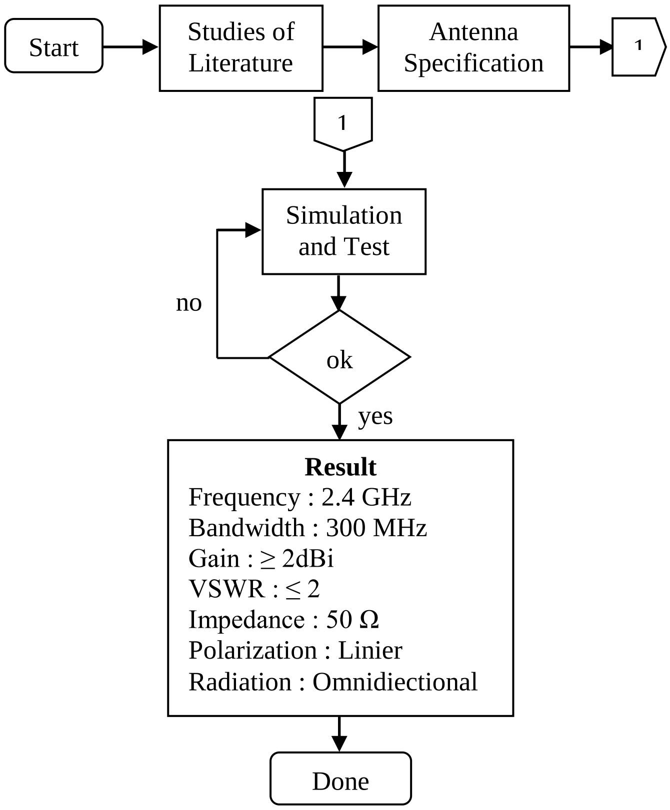

Fig. 1. Methodology of Research Flowchart

A. Design of Antenna

Next the process is designing the antenna, the first step is determine the antenna characteristics with parameters, namely:

- Middle frequency 2.40 GHz - 2.49 GHz
- Bandwidth of each band is ≥300 MHz
- VSWR ≤2
- Gain ≥2 dBi
- Impedance 50 Ω
- Linear polarization
- Omnidirectional radiation pattern
- 1.4 mm FR4 antenna material

Then determine the material and antenna coefficients in design of Micro-strip Antenna because the determination of the material will determine the quality of the signal transmission. In the study used materials for substrate and patch as follows:

1. Substrate
   Material: FR4-Lossy
   Koef: 4.3
   Thickness: 1.6 mm
2. Patch / Ground / feed
   Material: Cooper (Annealed)
   Thickness: 0.035 mm

After we determine the material and the coefficients to be used to design the antenna, then next we can determine the dimensions of the antenna with the following formula.

$$L = \frac{c}{2f\sqrt{\varepsilon_r}} \quad (1)$$

With the following constants

$c = speed\ of\ light\ (3 \times 10^8)$
$\varepsilon r = dielectric\ coeficient (4.3)$

After determining the characteristics and coefficients of antennas to apply in feeding then antennas are designed using CST Studio software, after inputting the characteristics and coefficients we want to eat the design results Shape and Dimension of Antenna (Fig. 2) and 3D Shape of Antenna (Fig. 3) from CST Studio are as follows:

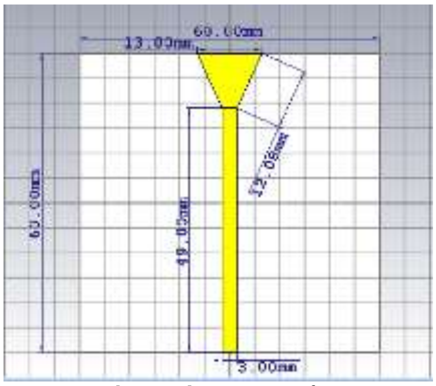

Fig. 2. Shape and Dimension of Antenna

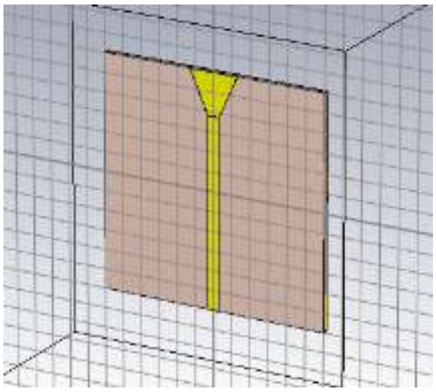

Fig. 3. 3D Shape of Antenna

B. S Parameter of Antenna

In determining the value of S parameters that have been obtained in the process of measuring antenna dimensions before. Then the next process of design there is a shift in frequency even though the values of W and L have corresponded to the calculations. So we have to do the iteration of the antenna parameters.

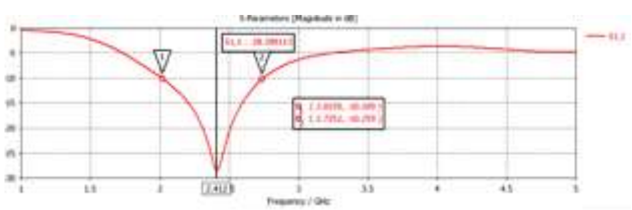

Fig. 4. S Parameter Antenna Simulation

After iterating to get the desired working frequency (fig. 4) that is 2.4012 GHz, we also can conclude that the main parameters that affect the working frequency of the width of the patch (W) and the length of the patch (L). So to get the desired working frequency the width and length of the patch should be set.

C. Port Impedance

Antenna must have impedance of port matching with impedance of transmission line of course we have to pay attention at feed and port. In this experiment, the desired impedance is 50 Ω. With the calculation process using the Macros toolbar, we get a port impedance of 50.154 Ω (Fig 5). The results are not much different from the desire at the time of design.

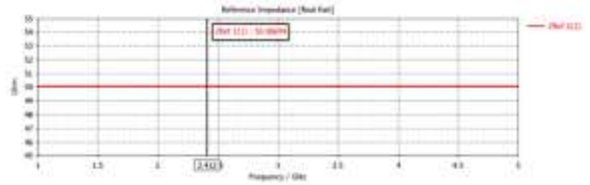

Fig 5. Port Impedance Antenna

D. Voltage Standing Wafe Ratio(VSWR)

Next simulation is to set VSWR value, simulation obtained is 1.0791366 as shown in Figure 6 below. Results in accordance with the desire that is where VSWR ≤ 2. VSWR value is influenced by the input impedance with transmission line impedance. The farther or less matching the two impedances are, the greater the VSWR value is obtained.

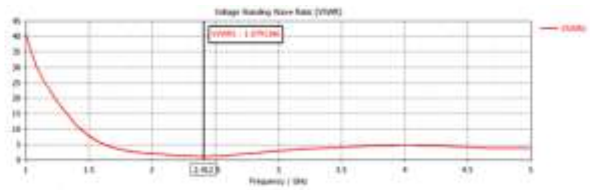

Fig. 6. VSWR Simulation

E. Bandwidth Antenna

From the simulation results in getting the bandwidth value of 719.4 MHz for a working frequency of 2.4 GHz As figure 7 shown.

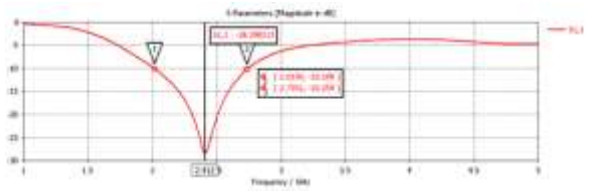

Fig. 7. Bandwidth Antenna Simulation

F. Antenna Impedance

Ideal condition of antenna impedance has same value with port impedance. So the value of VSWR obtained is not large. And the impedance from antenna at 2.4 GHz working frequency is 49.38Ω (fig. 8). The value of impedance is not far from the port transmit line is 50 Ω.

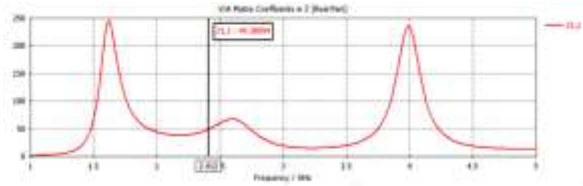

Fig 8. Antenna Impedance Simulation

G. Antena Gain

Antenna gain we have determined is ≥2 dBi, after the simulation results obtained Gain value of 3.140 dBi as seen in the following figure.

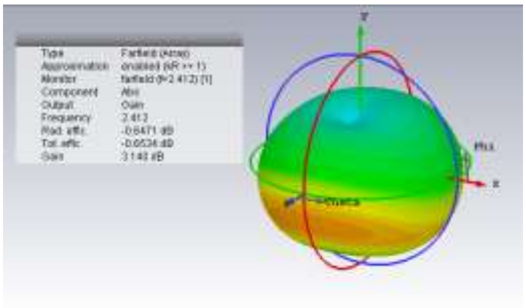

Fig. 9. Radiation pattern on 3D

To see more clearly the simulation result of antenna radiation below is pattern of radiation with 2 dimensional image.

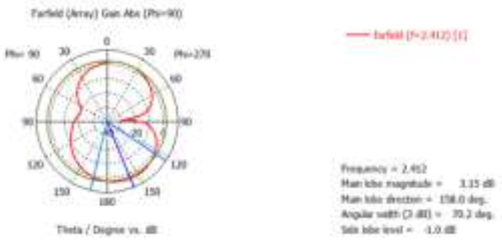

Fig. 10. Radiation pattern on 2D

From figure 10 it can be seen that the description of main lobe magnitude equals to 3.15 dB, which means that the design is successfully positioned gain to ≥2 dBi

III. ANTENNA FABRICATION AND LAB TEST

The next step is the process of fabrication the antenna, after going through the process of making then get the antenna shape figure11.

Fig. 11. Result of antenna fabrication

A. Laboratory test for S Parameter, SWR and Impedance

After the antenna already fabricated, next step is testing the antenna in LAB to make comparison between software simulation and real simulation after fabrication. The fabrication test is held in LIPI. This Antenna test is using ADVANTEST R3770 Network Analyzer tool, antenna is tested like the following figure 12.

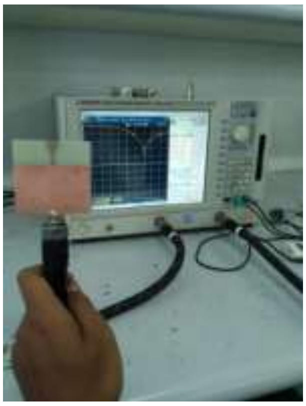

Fig. 12. Antenna test with network analyzer tool

The first test is S-parameter measurement to determines the antenna frequency position to work.

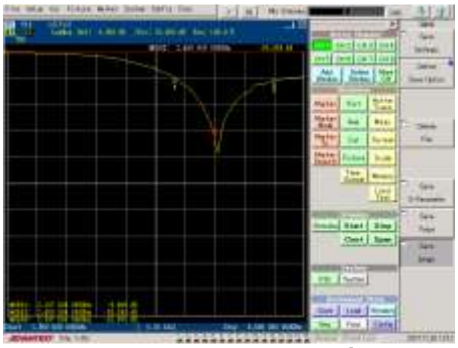

Fig. 13. S Parameter test result

From the curve view on the Anlyzer network above (Figure 13), it appears that the working frequency channel slightly complains the small shift to 2,402 GHz which is still within the working range of the desired specification and does not differ much from the software simulation results (Figure 4). After doing the test of the S Parameter then next proceed to test the SWR value.

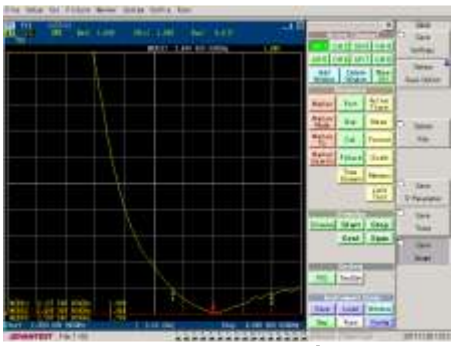

Fig. 14. SWR test result

From the Figure 14, SWR test results can be seen at the position of working frequency 2.4 GHz then the value of SWR generated by the antenna is 1.045 which means that the antenna made already meets the standard criteria for SWR is ≥ 2 and not much different from the software simulation results (Figure 6) which shows the position of SWR at the number 1.079. The last test was performed to test the value of the antenna impedance as follows.

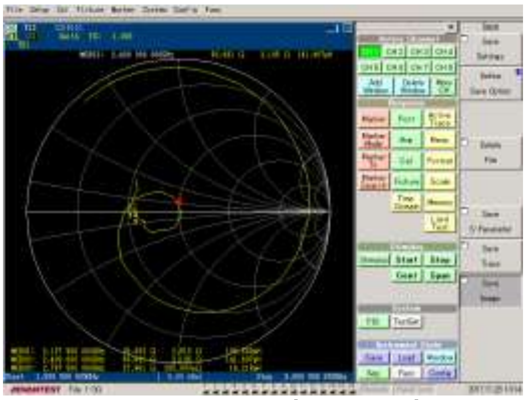

Fig. 15. Antenna Impedance test result

From the test results obtained antenna impedance position at 2.4GHz frequency is 50.691Ω adrift 0.69 from the ideal impedance value of antenna by 50 Ω where seen a slightly significant difference from the software simulance result (figure 10) that is 49.38Ω. After all laboratory test complete next compare betwen software simulation and laboratory test after fabrication, below is table of comparison.

TABLE I. Result Comparison.

Parameter	Ideal Character	Simulation Result	Laboratory Result
Working Frequency	2.4 GHz – 2.49 GHz	2.412 GHz	2.402 GHz
VSWR	≤ 2	1.0791	1.0450
Bandwidth	≥ 700 MHz	719.3 MHz	710.02 MHz
Port Impedance	50 Ω	50.006894Ω	50Ω
Antenna Impedance	50 Ω	49.38094Ω	50.691Ω
Gain	≥ 2 dBi	3.140 dB	3.3 dB

B. Signal Transmission Test

Next step after conducting a test on the basic antenna specifications and found the ideal result to be used as conductor signal then the next will be tested to prove whether the antenna can work to receive the signal. In this test the microstrip antenna will function as a signal recieve, whereas the antenna used as a transmitter is the antenna DRG (Double Ridge Guide) Horn Antenna with type SAS-200/571.

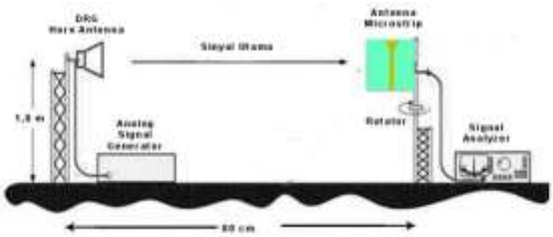

Fig. 16. Test Scheme

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Fig. 17. Real photos of antenna position

As shown in Figure 16 and 17 the position between the antenna is 80 cm and to start the test adjusts the amplitude position at 0.0 dbm and 2.4 GHz frequency on the Sinal Generator Analog tool such as Figure 18 below.

Fig. 18. Setup of analog signal generator

After adjusting the position of frequency and amplitude on the 'Analog Signal Generator' then the signal emitted through DRG Horn can be seen on the Signal Analyzer in figure 19 below.

Fig. 19. Signal receive on micro-strip antenna shown in signal analyzer

For clearly to see result from 'Signal Analyzer', the result is record the RSS (Receive Signal Strength) from antenna from any angel when antenna rotate, below is the table of result from 'Signal Analyzer'.

TABLE II. RSS data from antenna when rotate

No	Angle	RSS
1	0°	-31,94 dbm
2	45°	-35,98 dbm
3	90°	-35,93 dbm
4	135°	-32,87 dbm
5	180°	-32,95 dbm
6	225°	-35,24 dbm
7	270°	-37,23 dbm
8	315°	-34,98 dbm
9	360°	-30,98 dbm

IV. GSM TO INTERNET PROTOCOL REPEATER SYSTEM

The next step after antenna already fabricated and tested in laboratory is create the repeater from GSM signal to Internet Protocol. As mention in the introduction, the purpose of the repeater is to coverage the blank-spot area as shown in the figure 20 below.

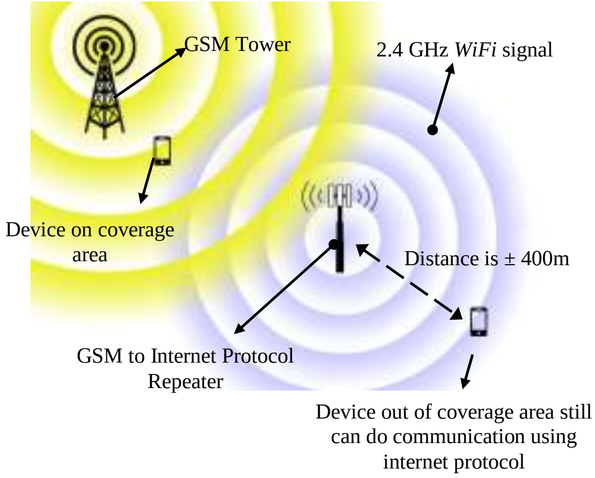

Fig. 20. Schematic of blank-spot area

In figure 19 clearly draw how the repeater system can connecting between 2 devices where the position of the first device is within the scope of the GSM signal while the second device is chested beyond the scope of the GSM signal. Using a router device consisting of Antenna, Router, Switch and GSM Converter Modem, the GSM signal is disconnected because the transmitter distance will be converted to internet protocol and will be forwarded through Wireless Fidelity (Wi-Fi) system with 2.4 GHz working frequency. Below is the antenna figure connected with TP-Link Access Point with TL-WA500G type with maximum power configuration for transmitter power.

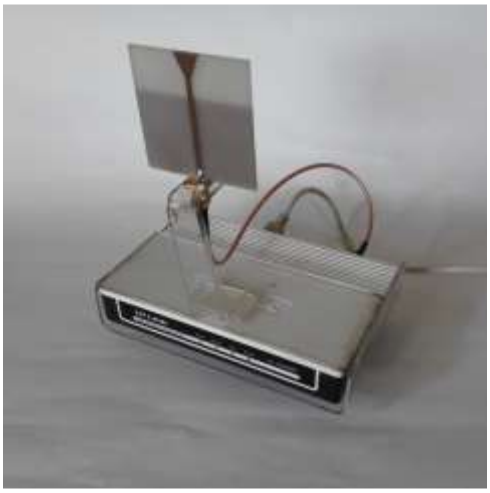

Fig. 21. Antenna connected to Wi-Fi Router

After the antenna already connected to the Wi-Fi router system, next the preparation for GSM to Internet Protocol device. The converter from GSM to Internet Protocol will use 3 devices to build the system.

1. Prolink 4G GSM Modem
2. Wireless N nano router TP-Link TL-WR702N
3. Mini HUB/SWITCH TP-Link SF1005D

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Below is image of GSM to Internet Protocol device when the set up already done.

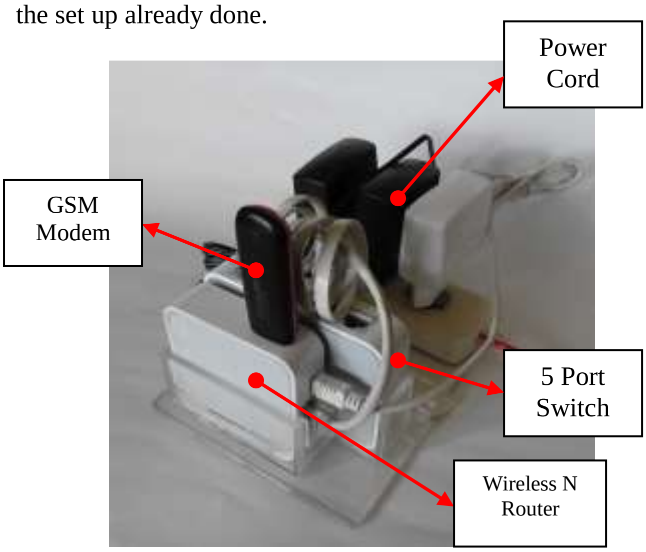

Fig. 22. GSM to internet protocol converter

Fig. 23. Measurement result with device distance on 1 m from Wi-fi AP

Fig. 24. Measurement result with device distance on 400 m from Wi-fi AP

For the next point preparation the device to connect with the GSM to Internet Protocol system, the device is Samsung Galaxy Tab A 2016. Make the condition where the device Samsung Galaxy TAB A 2016 is in a position outside the scope of GSM signals, for that we will connect with Access Point (AP) in order to stay able to communicate using internet protocol. To prove the effectiveness of antenna-designed feeding tests using open source software available on Google Playstore is WIFI Analyzer from Keuwlsoft which is downloaded and installed on the Samsung Galaxy TAB A 2016 to measure the effective distance between AP and Device. The results are shown in Figure. 23 and Figure 24 of the signal strength of the RSSI (Received Signal Strength Indication) signal received by the mobile device from the Access Point (AP) drive at a distance of 1 m (figure 23) and 400 m (figure 24), for attenuation pattern show in figure 25.

Fig. 25. Attenuation pattern when device move from Wi-Fi AP

V. Conclusion and Recommendations

A. Conclusions

From the test result which have been done can be concluded that antenna can meet the goals of success, the goals parameter is, working frequency = 2.402 GHz, VSWR = 1.0450, Bandwidth = 710.02 MHz, Port Impedance = 50Ω, Impedance Antenna = 50.691Ω, Gain = 3.3 dB and result from direct implementation antenna on repeater system can work well.

B. Recommendations

Based on the results of design, simulation and trial then it can be given suggestions as follows:

1. On laboratory test the value of Impedance and SWR antenna had shifted away from ideal, hence required use of port connector with good quality so that output impedance and SWR as ideal.
2. The selection of basic materials between those available in the CST Studio software and those on the market are not always the same despite one type, it is necessary to test and compare the physical before the material is really ready to be fabricated into an antenna, because it will be crucial due to material errors .
3. Practical development of the antenna requires a directional transmitting pattern to complete the signal successor system..

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