JURNAL INFOTEL
Informatics - Telecommunication - Electronics
Website Jurnal : http://ejournal.st3telkom.ac.id/index.php/infotel
ISSN : 2085-3688; e-ISSN : 2460-0997

Multipath Effects in Building Environment toward Bandwidth Enhancement for Mobile Communication of 47 GHz Frequency

Andrita Ceriana Eska
Electrical Engineering Department, University of Jember
Kalimantan Street 37 Kampus Tegalboto, Pos 159 Jember, Indonesia
Corresponding email : andritacerianaeska@gmail.com

Received 8 January 2018, Revised 19 February 2018, Accepted 24 February 2018

Abstract — This paper focused on the communication system with multipath effects at buildings environment. The frequency used for the communication system was 47 GHz. The condition of the communication propagation used downlink direction. Mobile station was placed at the tracks or streets around buildings environment. This research analysis was based on transmitter power variation, bandwidth variation, and modulation threshold variation. That analysis produced signal to noise ratio value from the relation between bandwidth and transmitter power variation. The transmitter power variation that used was consist of 0.01 Watt, 0.1 Watt, and 1 Watt. Threshold variations for the communication modulation that used were 16 QAM and 64 QAM. The results showed that signal to noise ratio decreases for wider bandwidth, whereas it increases for higher transmitter power.

Keywords – building, bandwidth, multipath, modulation.

I. INTRODUCTION

The communication system was developed continuously, many kinds of the research keeps going developed. The use of millimeter wave was for research still developed. The use of high frequency can be influenced by atmospheric attenuation. Some of the research related about high frequency used of communication systems such as 38 GHz and 60 GHz frequency for wireless peer to peer communication in urban area where propagation can be occurred by multipath because of building existence [1], propagation for RBS femtocell communication used 10 GHz frequency at street lamp pole [2], the code rate influence that used at communication system of RBS femtocell using 47 GHz frequency at street lamp pole [3], research that used 2.3 GHz frequency for mobile communication system of tree obstacles [4], research about loss diffraction analysis of NLOS for small cell backhaul used millimeter wave [5], handoff mechanisms for 60 GHz at wireless systems [6], and propagation mechanisms for handoff at 5G mobile communication [7], propagation model of millimeter wave communication at 5G Wireless Networks [8], diffraction upon building at millimeter wave mobile communication systems [9], and determination location mobile station using 47 GHz frequency [10].

The priority problems that occurred at the mobile antenna was below the surrounding buildings, so there is no line-of-sight path to the transmitter. That propagation majority can be occurred by scattering from the surface of the buildings and by diffraction around them [11]. At the communication, propagation can be influenced by multipath that spread to receiver, so multipath that occurred was from Radio Base Station (RBS) toward mobile station (MS) or from MS toward RBS. The amount that spreads dependent on the distance between mobile station and radio base station location. The signal to noise ratio (SNR) value can be defined by modulation threshold value at the communication systems, such as research about the communication simulation between a car and another car that used BPSK, QPSK, 16 QAM, and 64 QAM modulation [12].

This research was focused on mobile communication system with downlink condition. The frequency that used was 47 GHz. The usage that frequency was influenced by atmospheric attenuation. The mobile station was moving at track around buildings environment, so that communication propagation was influenced by multipath mechanism. The buildings' height at that buildings environment created with different height, such as 10 meters to 60 meters. The analysis of this research that used such as transmitter power variation, bandwidth variation, and modulation variation. Transmitter power variation was used from 0.01 Watt until 1 Watt. Bandwidth variation that used was consist of 5 MHz until 25 MHz with 8 channel. Modulation variation that used for 16 QAM was consist of code rate 1/2, 2/3, 3/4, and 4/5. Modulation variation that used for 64 QAM was consist of code rate 2/3, 3/4, and 4/5. The communication threshold such as SINR value was consist of SNR value with IM (Implementation Margin) [13]. The results of this research that obtained were multipath and pathloss SNR value, with transmitter power variation, bandwidth variation, modulation threshold variation, and percentage of coverage area based mobile station movement at track.

II. RESEARCH METHOD

This research that accomplished model for communication environment condition, can be viewed in Fig.1. The buildings height variation that used was from 10 meters to 60 meters. The distance between buildings that modeled by 20 meters was consist of 14 meters for double ways wider, 2 meters for sidewalk, and 4 meters for garden. The mobile station track used as far as 600 meters. The figure that observed many lines around buildings, and more specific can be seen in Fig.2. The perfect reflection mechanism at the surface of every building was used at that model. That lines showed multipath that spread among buildings, where propagation track was from RBS to MS track. RBS height that used was 30 meter, and MS height was 1.5 meter. Fig.3 showed the buildings from above.

The communication frequency that used was 47 GHz. The use of that frequency influenced by atmospheric attenuation, can be seen in Fig.3. At that figure showed the relation between frequency and atmospheric attenuation [14]. The equation for attenuation path can be seen (1),

$$A = \gamma r_o = (\gamma_o + \gamma_w)\, r_0\, dB \tag{1}$$

At Equation (1) showed the parameter r_0 can be expressed as path length (km), the parameter γ can be expressed as gaseous attenuation, the parameter γ_o can be expressed as attenuations for dry air (dB/km), the parameter γ_w can be expressed as attenuations for water vapour (dB/km), and the parameter A can be expressed as path attenuation. The use of γ_o parameter for frequency $\leq 54\ GHz$, can be seen (2).

$$\gamma_o = \left[\frac{7.2\, {r_1}^{2.8}}{f^2 + 0.34\, {r_p}^2 {r_t}^{1.6}} + \frac{0.62\, \xi_3}{(54-f)^{1.16\xi_1} + 0.83\, \xi_2}\right] \times f^2 {r_p}^2 \times 10^{-3} \tag{2}$$

Equation (2), the parameter f can be expressed by frequency (GHz). The equation for ξ_1, ξ_2, ξ_3 value can be seen (3).

$$\begin{aligned} \xi_1 &= \varphi\,(r_p, r_t, 0.0717, -1.8132, 0.0156, -1.6515) \\ \xi_2 &= \varphi\,(r_p, r_t, 0.5146, -4.6368, -0.1921, -5.7416) \\ \xi_3 &= \varphi\,(r_p, r_t, 0.3414, -6.5851, 0.2130, -8.5854) \end{aligned} \tag{3}$$

The parameter for r_p obtained from $r_p = \rho_{tot}/1013$, the parameter p_{tot} can be expressed as air pressure total, and the parameter r_t can be expressed as pressure (hPA). The parameter γ_w can be seen (4).

$$\begin{aligned} \gamma_w = \Bigg\{ & \frac{3.98\,\eta_1 \exp[2.23(1-r_t)]}{(f-22.235)^2 + 9.42{\eta_1}^2}\, g(f,22) + \frac{11.96\eta_1 \exp[0.7(1-r_t)]}{(f-183.31)^2 + 11.14{\eta_1}^2} \\ & + \frac{0.08\eta_1 \exp[6.44(1-r_t)]}{(f-321.226)^2 + 6.29{\eta_1}^2} + \frac{3.66\eta_1 \exp[1.6(1-r_t)]}{(f-325.153)^2 + 9.22{\eta_1}^2} \\ & + \frac{25.37\eta_1 \exp[1.09(1-r_t)]}{(f-380)^2} + \frac{17.4\eta_1 \exp[1.46(1-r_t)]}{(f-448)^2} \\ & + \frac{844\eta_1 \exp[0.17(1-r_t)]}{(f-557)^2}\, g(f,557) + \frac{290\eta_1 \exp[0.41(1-r_t)]}{(f-752)^2}\, g(f,752) \\ & + \frac{8.332x10^2\eta_1 \exp[0.99(1-r_t)]}{(f-1780)^2}\, g(f,1780) \Bigg\} \times f^2 {r_1}^{2.5} \rho \times 10^{-4} \end{aligned} \tag{4}$$

Values for η_1 and η_2 parameters can be seen (5).

$$\begin{aligned} \eta_1 &= 0.955 r_p {r_t}^{0.68} + 0.006\rho \\ \eta_2 &= 0.735 r_p {r_t}^{0.5} + 0.0353 {r_t}^4 \rho \end{aligned} \tag{5}$$

The parameter ρ can be expressed as water-vapor density (g/m^3). The parameter $g(f, f_i)$ can be seen (6), the parameter f can be expressed as frequency (GHz), and the parameter i can be expressed as numbers variation, $i = \{1,2,3,4,\ldots\}$.

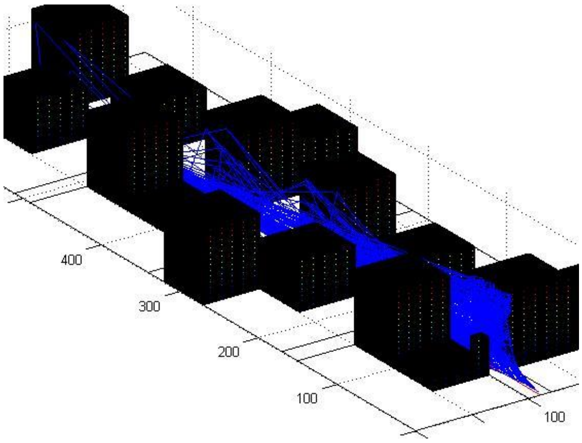

Fig. 1. The Communication System Model at Buildings Environment

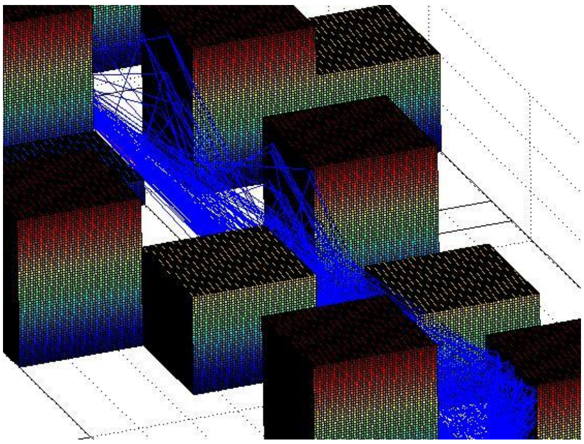

Fig. 2. Multipath Model Around Buildings

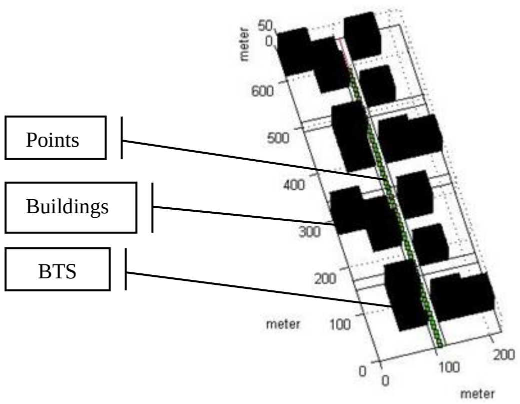

Fig.3. The Buildings Model from Above

$$g(f, f_1) = 1 + \left(\frac{f - f_i}{f + f_i}\right)^2 \quad (6)$$

The equation for determination of link margin value can be seen (7), where EIRP, L_{path}, G_{rx}, and TH_{rx} are represented by effective isotropic radiated power, path loss total, receive gain (dB), and receiver threshold or minimum received signal level (dBW or dBm) [15]. The transmitter power variation that used was consist of 0.01 Watt, 0.1 Watt, and 1 Watt.

$$Link\ margin = EIRP - L_{path} + G_{rx} - TH_{rx} \quad (7)$$

The equation for determinate free space loss value, can be seen (8), where λ, G_T, G_R, and d are represented by wave length, gain transmitter, gain receiver, and communication distance [15].

$$L = G_T . G_R . \left(\frac{\lambda}{4\pi d}\right) \quad (8)$$

The equation for noise at communication system can be seen (9), where K, B, T_o, and F are represented by Boltzman constant, bandwidth, standard noise temperature, and noise figure [15]. The bandwidth variation that used was 5 MHz until 25 MHz with 8 channel.

$$N = k\, T_0\, B\, F \quad (9)$$

The parameter F is given by (10).

$$F = \left(1 + \frac{T_e}{T_0}\right) \quad (10)$$

Where T_e and T_o are represented by noise temperature at receive and standard noise temperature. The noise figure value that used was 7 dB. The signal to noise (SNR) value is given by (11)

$$SNR = \frac{S}{N} \quad (11)$$

Where S and N are representations of signal and noise [15].

III. RESULT

The research result can be seen in this part. At this part was showed the research result. Mobile station was moving at track as far as 600 meters, around the mobile station track existed building with varying height. The communication frequency that used was 47 GHz, so that was influenced by atmospheric attenuation. Some of the variations those used consisted of transmitter power variation, bandwidth variation, and threshold variation at modulation. The result was showed by comparison between SNR multipath and SNR path loss value. That comparison value was based on value variation from coverage area percentage, transmitter power variation, bandwidth variation, and modulation threshold for 16 QAM and 64 QAM.

Figure 4 showed SNR multipath and SNR path loss for transmitter power 0.01 Watt. Some of the data from that figure such as when mobile station as far as 14 meter and bandwidth that used was 5 MHz with 8 channel or 40 MHz, that was obtained SNR value for path loss 43.2 dB and SNR value for multipath 38.57 dB. The decrease of SNR value caused path loss distance around 46.99 meter and multipath distance around 80.07 meters. When that bandwidth used 25 MHz with 8 channel or 200 MHz that was obtained SNR value for path loss around 36.21 dB, and SNR value for multipath around 31.58 dB.

https://doi.org/10.20895/infotel.v10i1.353

When mobile station as far as 500 meters and bandwidth that used was 5 MHz with 8 channels, that obtained SNR value for path loss 23,45 dB and SNR value for multipath 22,77 dB. The decreasing of SNR value caused path loss distance around 451,01 meter and multipath distance around 487,47 meter. When bandwidth used 25 MHz with 8 channel was obtained SNR value for path loss around 16,46 dB, and SNR value for multipath around 15,78 dB.

Figure 5 showed SNR multipath and SNR path loss for transmitter power 0.1 Watt. Some of the data from that figure such as when mobile station as far as 14 meter and bandwidth that used was 5 MHz with 8 channel or 40 MHz, that was obtained SNR value for path loss 53.2 dB and SNR value for multipath 48.57 dB. The decreasing of that SNR value caused path loss distance around 46.99 meter and multipath distance around 80.07 meters. When using bandwidth used 25 MHz with 8 channel or 200 MHz, that was obtained SNR value for path loss around 46.21 dB, and SNR value for multipath around 41.58 dB.

When mobile station as far as 500 meters and bandwidth that used was 5 MHz with 8 channels, that obtained SNR value for path loss 33.45 dB and SNR value for multipath 32.77 dB. The decreasing of SNR value caused path loss distance around 451.01 meter and multipath distance around 487.47 meters. When bandwidth used 25 MHz with 8 channel, that was obtained SNR value for path loss around 26.46 dB, and SNR value for multipath around 25.78 dB.

Figure 6 showed SNR multipath and SNR path loss for transmitter power 1 Watt. Some of the data from that figure such as when mobile station as far as 14 meter and bandwidth that used was 8 MHz with 8 channels, that was obtained SNR value for path loss 63.2 dB and SNR value for multipath 58.57 dB. The decreasing of SNR value caused path loss distance around 46.99 meter and multipath distance around 80.07 meters. When bandwidth used 25 MHz with 8 channels, that was obtained SNR value for path loss around 56.21 dB, and SNR value for multipath around 51.58 dB.

When mobile station as far as 500 meters and bandwidth was used 5 MHz with 8 channel, that obtained SNR value for path loss 43.45 dB and SNR value for multipath 42.77 dB. The decreasing of SNR value caused path loss distance around 451.01 meter and multipath distance around 487.47 meters. When using bandwidth used 25 MHz with 8 channel, that was obtained SNR value for path loss around 36.46 dB, and SNR value for multipath around 35.78 dB.

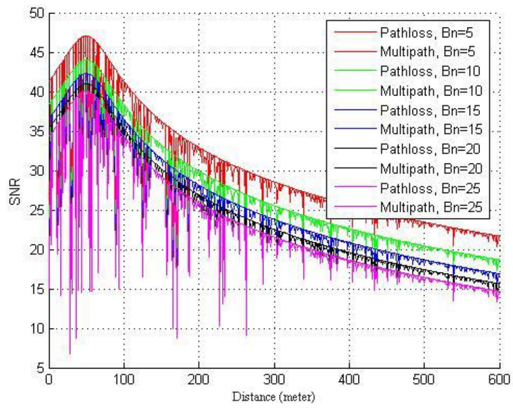

Fig. 4. SNR for Transmitter Power 0.01 Watt

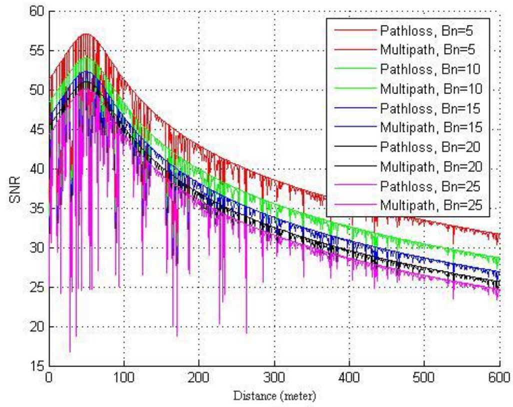

Fig. 5. SNR for Transmitter Power 0.1 Watt

Figure 7 showed the resulting percentage for coverage area from threshold SNR minimum that was consist of 16 QAM and 64 QAM. When transmitter power at RBS 0.01 Watt, bandwidth 5 MHz with 8 channel or 40 MHz, threshold 16 QAM with code rate 2/3 produced coverage area around 99.83%, and code rate 3/4 produced coverage area around 97.33%. When bandwidth that used was 20 MHz with 8 channels or 160 MHz, threshold 16 QAM with code rate 2/3 produced coverage area around 98.67%, and code rate 3/4 produced coverage area around 94.33%. When threshold 64 QAM with code rate 3/4 produced coverage area around 48.83%.

Figure 8 showed the resulting percentage for coverage area with threshold SNR minimum of 16 QAM and 64 QAM. When transmitter power at RBS using 0.1 Watt, bandwidth 5 MHz with 8 channel or 40 MHz, threshold 16 QAM with code rate 2/3, and 4/5 produced coverage area around 100%, code rate 4/5 produced coverage area around 100%, and if using threshold 64 QAM with code rate 3/4 produced coverage area around 100%. When bandwidth that used was 20 MHz with 8 channels or 160 MHz, threshold 16 QAM with code rate 2/3 produced coverage area around 100%, code rate 3/4 produced coverage area around 100%, and if using threshold 64 QAM with code rate 3/4 produced coverage area around 99%.

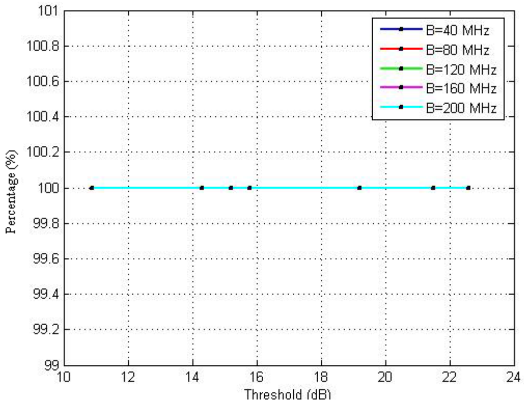

Fig. 6. SNR for Transmitter Power 1 Watt

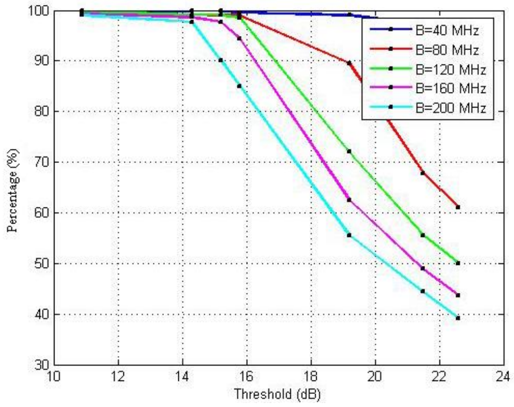

Fig.7. The Coverage Percentage When Transmitter Power 0.01 Watt

Figure 9 showed the resulting percentage for coverage area with threshold SNR minimum of 16 QAM and 64 QAM. When transmitter power at RBS using 1 Watt, bandwidth 5 MHz with 8 channels or 40 MHz, threshold 16 QAM with code rate 2/3 produced coverage area around 100%, code rate 4/5 produced coverage area around 100%, and if using threshold 64 QAM with code rate 3/4 produced coverage area around 100%. When bandwidth that used 20 MHz with 8 channel or 160 MHz, threshold 16 QAM with code rate 2/3 produced coverage area around 100%, code rate 3/4 produced coverage area around 100%, and using threshold 64 QAM with code rate 3/4 produced coverage area around 100%.

The research result shows wider bandwidth that used, so SNR value more decrease. When transmitter power that used more increase, so SNR value more increase. That research data based on parameter that consist of threshold 16 QAM with code rate 2/3, and bandwidth 40 MHz from 5 MHz with 8 channel, produced percentage of coverage area such as for transmitter power 10 dBm was obtained around 98.83%, for transmitter power 20 dBm, and 30 dBm was obtained around 100%. The percentage value of coverage area when used code rate 4/5, for transmitter power 10 dBm was obtained around 99.5%, for transmitter power 20 dBm, and 30 dBm was obtained around 100%. The percentage value of coverage area when parameter that used such as threshold 64 QAM with code rate 3/5, for transmitter power 10 dBm was obtained around 97.33%, for transmitter power 20 dBm, and 30 dBm was obtained around 100%.

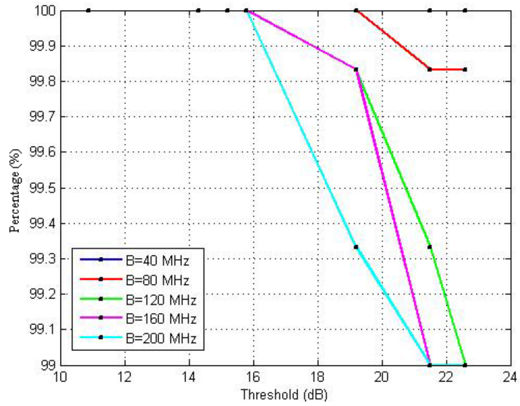

Fig.8. The Coverage Percentage When Transmitter Power 0.1 Watt

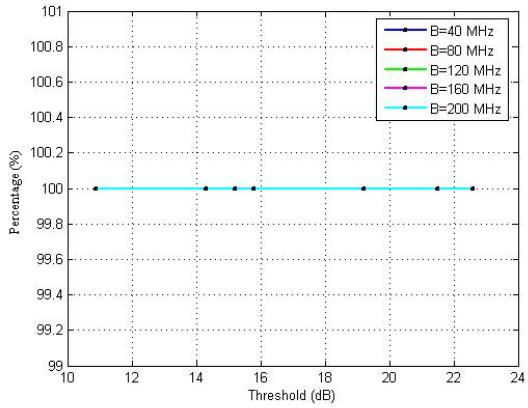

Fig. 9. The Coverage Percentage When Transmitter Power 1 Watt

IV. DISCUSSION

The research result data showed more increase transmitter power, then more increase at SNR path loss. That data showed changes at transmitter power was consist of 0.01 Watt, 0.1 Watt, and 1 Watt. SNR path loss that was obtained more decrease when more far of mobile station. SNR multipath that was influenced buildings become more low then SNR pathloss. The wider bandwidth that was used then SNR value more decrease. The transmitter power that was used more increase then SNR value more increase.

Some of the comparison data for SNR path loss and multipath based on power transmitter and bandwidth such as when MS as far as 14 meters, transmitter power 0.01 Watt and bandwidth 5 MHz, then SNR path loss was obtained around 43.2 dB and SNR multipath was obtained around 38.57 dB, for bandwidth 25 MHz then SNR path loss was obtained around 36.21 dB and SNR multipath was obtained around 31.58 dB. The comparison from code rate with the percentage of coverage area, showed more increase code rate value that was used then lower percentage of coverage area. Some of that data such as when transmitter power 0.01 Watt and bandwidth 5 MHz for modulation 16 QAM with code rate 2/3 was obtained around 99.83%, whereas code rate 4/5 was obtained around 99.5%. The comparison from modulation variation with the percentage of coverage area was showed 64 QAM modulation was obtained percentage of coverage area lower than 16 QAM modulation with same code rate. Some of that data such as when transmitter power 0.01 Watt and bandwidth 5 MHz for 16 QAM modulation with code rate 3/4 was obtained around 99.83%, whereas 64 QAM modulation with code rate 3/4 was obtained around 97.33%. The comparison from bandwidth variation with the percentage of coverage area, showed the wider bandwidth that used, then more decrease percentage of the coverage area. Some of that data such as when transmitter power 0.01 Watt with 16 QAM modulation with code rate 2/3 for bandwidth 5 MHz was obtained around 99.83%, whereas bandwidth 40 MHz was obtained around 97.67%.

V. CONCLUSION

The multipath influenced at communication system around buildings environment that used 47 GHz frequency. The usage that high frequency possibly used wider for bandwidth. The result from research based on transmitter power variation, bandwidth variation, and threshold modulation variation, showed multipath influence was caused SNR value become decrease, but that SNR value can increase when transmitter power more increase. The comparison between modulation with the percentage of coverage area, showed the percentage of coverage area from modulation 64 QAM smaller than modulation 16 QAM for same code rate. The comparison code rate with the percentage of coverage area, showed the higher code rate that used then the smaller the percentage of coverage area. The comparison between bandwidth with the percentage of coverage area, showed more increase bandwidth variation that used then the smaller percentage of coverage area.

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