



Outage Performances of 5G Channel Model Influenced by Barometric Pressure Effects in Yogyakarta

Solichah Larasati^{1*}, Serli Ridho Yuliani², Achmad Rizal Danisya³

^{1,2,3}Institut Teknologi Telkom Purwokerto

^{1,2,3}Jl. D.I Panjaitan No.128 Purwokerto, Banyumas, Jawa Tengah, Indonesia

*Corresponding email: laras@ittelkom-pwt.ac.id

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Abstract — The fifth-generation cellular technology (5G) is predicted to adopt a high-frequency channel, which could lead to a new challenge, namely, wave propagation attenuation. This attenuation is affected by natural conditions, such as barometric pressure, rain rate, humidity, and vegetation density. This paper proposes a 5G channel model under the barometric pressure effect to address the issue. The channel model is obtained from series computer simulations by operating frequency of 28 GHz and real-field parameters of Yogyakarta environments. The 5G channel model frameworks consist of two steps. First, generate the instantaneous Power Delay Profile (PDP) using NYU Wireless Simulator with real-field parameters of the environment. Second, the instantaneous PDP is then used to calculate the representative PDP. PDP differs from one country to another, especially on 5G technology, because of the high-frequency band, which is sensitive to nature. To observe the barometric pressure effect, we need to generate the instantaneous PDP with minimum and maximum barometric effects. PDP value used to calculate the outage probability of channel capacity (C) is smaller than the coding rate (R), indicating a failure of detection at the receiver based on the Shannon theory. Outage probability is obtained by the cumulative distribution function of the capacity evaluated against the coding rate. Outage probability results in both scenarios can reach a point of 10^{-4} , for coding rate $\frac{1}{2}$ needs 17.649883 dB, coding rate $\frac{3}{4}$ needs 20.020953 dB, and coding rate 1 needs 22 dB. This shows that barometric does not significantly influence the performance of the 5G communication system.

Keywords – 5G, Channel Model, Power Delay Profile, Outage Probability, Barometric pressure

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I. INTRODUCTION

The development of telecommunications technology needs to be accompanied by the increase of various services, encourages cellular technology to evolve [1]. The evolution of cellular technology has now reached the fifth-generation (5G), where this technology is expected to be launched in 2020 [2], [3]. The cellular technology that will be released in 2020 supports a variety of usage scenarios and applications, namely enhanced mobile broadband, ultra-reliable and low-latency communication, and massive machine type communications [4]. The limited frequency spectrum for cellular wireless communication needs (such as 2G, 3G, and 4G) is a driving factor in determining the search for new frequency bands for 5G wireless communication [5].

The 5G technology is predicted to use frequencies between 500 MHz - 100 GHz [6]. Frequency distribution for 5G technology is divided into three categories, namely Rural (<1 GHz), Urban (1-6 GHz), and Urban Hotspot (>6 GHz) [7]. One of the candidates for frequency in 5G technology is the frequency of 28 GHz, which frequency will be used as a working frequency in this research. This high-frequency present a new challenge, namely the problem of wave propagation attenuation, which is strongly influenced by natural geographical conditions such as rainfall, temperature, humidity, barometric and vegetation density [8]. The difference in the shape of the earth's contour and the natural conditions in each region requires research to find the most appropriate channel model to be used in the region.

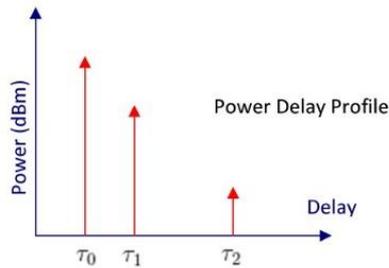


Fig. 1. Channel Impulse Response: An Example Transmitted Signal with Different Signal Power and Different Propagation Delays.

The channel is a medium between the sending antenna and receiving antenna, where the channel needs to be modeling to produce a communication system design that minimizes errors and maximizes information transmission or bit rate. The power delay profile represents the average power associated with a given multipath delay as a propagation delay function [9]. The PDP is obtained as the spatial average of the complex baseband channel impulse response. The example of Power Delay Profile (PDP) is shown in Fig. 1, Y-axis represents the signal power of each multipath, and the X-axis represents the respective propagation delays.

The multipath phenomenon that occurs due to reflection, diffraction, and scattering causes the PDP value to fluctuate. So, this channel model requires the Statistical Spatial Channel Model (SSCM), which uses data from many experiments on channel parameters and probabilities that are statistically modeled. In This research used NYUSIM software to obtain the validation results, where the measurement values approach in the field. The channel model is designed as a proof of telecommunications technology because channel capacity influences system performance. If the channel model of the specific region is known, it can set related parameters to maximize the system performance.

The performance of the 5G technology system was obtained from the calculating of the outage probability from PDP. PDP was processed based on the principles of information theory, coding rate, and frequency. Outage probability is the probability that the channel coding rate (R) is higher than the channel capacity (C), which indicates transmission failure based on Shannon's theory [10] [11].

There are several existing and ongoing kinds of researches worldwide targeting on the 5G channel measurement and modeling [12]. The study is including mobile and wireless communication enablers for twenty-twenty (2020) Information Society (METIS)202 [13]. European telecommunication standards institute (ETSI) mmWave SIG [14], 5G mmWave Channel Model Alliance [15], millimeter-

wave based mobile radio access network for fifth-generation integrated communication (mmMagic) [16]. There is a lot of channel model research on 5G technologies worldwide, but the 5G channel model is profoundly affected by natural environments (e.g., foliage effect, temperature, humidity, rain rate, etc.).

This research focuses on the design and simulation of the 5G channel model to determine system performance with a barometric effect. The channel model is obtained based on the representative value of PDP at a frequency of 28 GHz under the influence of minimum and maximum barometric pressure, using the environment parameter represented by the Yogyakarta city.

The contributions of this paper are summarized as follows:

- a) We propose a 5G channel model simulated in Yogyakarta city.
- b) We provide a framework to calculate the channel model and its performance by using the real-field parameter of any locations in Indonesia.
- c) We present an outage performance 5G channel model under the barometric effect, which can be used as a reference to set the parameter of 5G Implementation in Indonesia.

II. RESEARCH METHOD

A. Environment Parameter

This study uses a working frequency of 28 GHz with a bandwidth of 50 MHz with a non-line of sight (NLOS) conditions with a distance between the transmitter and receiver as far as 50 meters and based on OFDM numerology for 5G cellular communication in the city of Yogyakarta. In this research, there are two scenarios, namely channel modeling under the influence of minimum barometric and maximum barometric influence. The environment data was obtained from the Climatology and Geophysics Meteorology Agency (BMKG) with data collection period from May 2017 - May 2019, which were then averaged. Data that has been obtained from BMKG will be input on the NYUSIM simulator. The proposed framework block of 5G channel model simulation under foliage effect is shown in Fig. 2.

B. Power Delay Profile (PDP)

The PDP is obtained as the spatial average of the complex baseband channel impulse response. PDP $A_c(\tau)$, also called as the multipath intensity profile, is defines as the auto-correlation which expressed as:

$$\Delta t = 0 : A_c(\tau) \triangleq A_c(\tau, 0), \quad (1)$$

PDP is characterized by the maximum excess delay, mean excess delay, and root mean square delay.

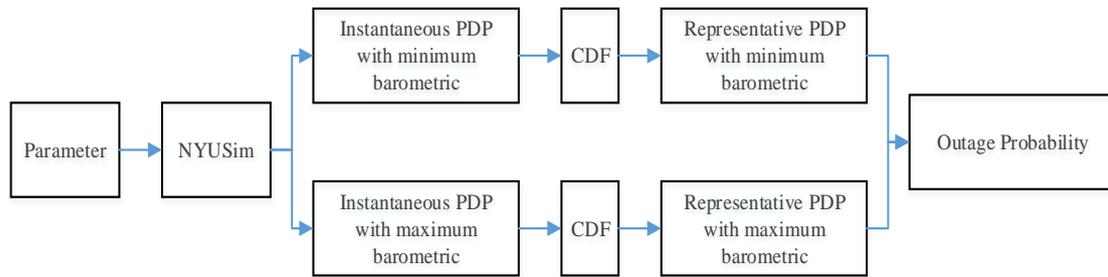


Fig. 2. Proposed Framework to Observe 5G Channel Model Under Barometric Effect.

a) Maximum Excess Delay

Maximum excess delay, which also called as maximum delay spread T_{max} , is the time difference between the first received signal component and the last signal component whose power level is above the receiver sensitivity.

b) Mean Excess Delay

Mean excess delay μT_m is the first moment of PDP. Mean excess delay can be calculate as,

$$\bar{\tau} = \frac{\sum_{k=0}^k P(\tau_k) \cdot \tau_k}{\sum_{k=0}^k P(\tau_k)} \tag{2}$$

where $A_c(\tau_k)$ is a signal power received in time τ_k .

c) Root Mean Square (RMS) Delay Spread

RMS delay spread can be calculate as:

$$\sigma_{\tau} = \sqrt{\bar{\tau}^2 - (\bar{\tau})^2} \tag{3}$$

where $\bar{\tau}^2$ is mean square excess delay spread, can be calculate as

$$\bar{\tau}^2 = \frac{\sum_{k=0}^k P(\tau_k) \cdot \tau_k^2}{\sum_{k=0}^k P(\tau_k)} \tag{4}$$

C. NYUSIM Simulation

NYUSIM has features that make channels that can be modeled under a specific condition with certain parameters. Parameters that can be set there are: frequency, bandwidth, scenario, transmitter power, the distance between transmitter and receiver, and environment parameters include barometric pressure, humidity, air temperature, and rainfall. The output of NYUSIM simulation results is in the form of instantaneous PDP, consisting of power and delay for each path.

The following are the input parameters in the NYUSIM simulator as in Table 1.

Table 1. NYUSIM Input Parameter

Parameter	Value
Frequency	28 GHz
Radio Frequency (RF) Bandwidth	50 MHz
Scenario	UMi
Environment	NLOS

Parameter	Value
Tx Power	30 dBm
T-R separation distance lower bound	50 meters
T-R separation distance upper bound	50 meters
Minimum barometric pressure	987.34 mbar
Maximum barometric pressure	995.27 mbar
Humidity	81.44 %
Temperature	26.26 °C
Rain rate	150 mm/h
Polarization	Set into Co-Polarization.
Foliage loss	No
Distance within foliage	0 m
Foliage attenuation	0 dB/m
Number of Rx location	1000

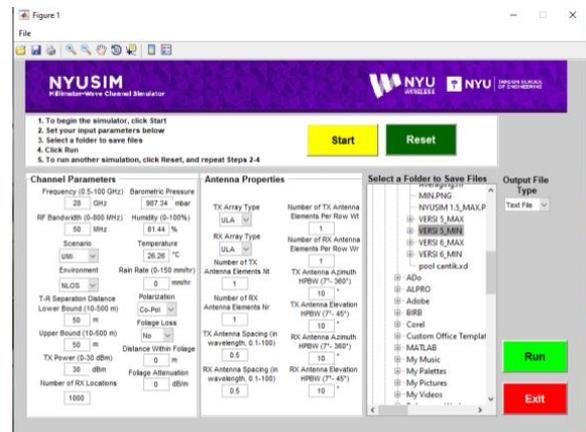


Fig. 3. NYUSIM Simulation.

D. Instantaneous PDP

We proposed the experiment instantaneous PDP from channel model Yogyakarta using 1000 Rx. From 1000 experiments will produce a PDP representative that is used to calculate channel capacity [17].

E. Representative PDP

The next step is to calculate to get a PDP representative. Steps to obtain rep representative PDP data that has been carried out in the study [10], [11]:

1. Convert PDP_i from dBm to numeric form, $i = \{1, 2, \dots, K\}$, where i is the index number of PDP and K is the total of PDP.
2. Next is to do grouping index, we consider grouping index $\alpha = 40$ and $l = 1, 2, \dots, L$ where L is the total timeslot τ in PDP divided by α .

$$\tau_{(l-1).\alpha+1}^{PDPi} = \frac{1}{\alpha} \cdot \sum_{n=(l-1).\alpha+1}^{l.\alpha} \tau_n^{PDPi} \quad (5)$$

3. Combine each $\tau_{(l-1).\alpha+1}$ of the overall PDP_i and calculate the CDF.
4. To determine a representative power value for each CDF path calculated by the 90th percentile because more data is of small value, and it is considered appropriate to choose representative data for 1000 PDP.
5. Doing thresholding of -150 dBm from a representative PDP and values below -150 dBm are considered as noise. Thresholding -150 dBm as an assumption for the sensitivity of 5G devices in Indonesia in the future.

F. Capacity and Outage Performance

The obtained representative PDP 5G channel model Yogyakarta with a barometric effect is then used to calculate the capacity and outage performance. The calculating of capacity on the broadband channel as modification from Shannon theory can be calculated as

$$\frac{C}{B} \approx \frac{1}{N} + \sum_{n=1}^N \log_2 \left(1 + (m \cdot R \cdot (|\Psi_n|^2 \cdot \frac{E_b}{N_0} \cdot \frac{N}{N+Q})) \right), \quad (6)$$

where N is a length block transmission, m is the modulation index, R is coding rate, and cyclic prefix length is denoted by Q .

Outage performance is needed to design an optimum system, where the performance can be calculated using CDF of the channel capacity. Outage probability P_{out} is a probability when the capacity C is dropped below the coding rate, expressed as [18]:

$$P_{out} = P_r(R > C) \quad (7)$$

By assuming that Shannon capacity is achieved such that $R = C$, we can obtain the theoretical outage performance of 5G channel model Yogyakarta under barometric effect.

III. RESULT

In this section will discuss the simulation result to the 5G channel model of Yogyakarta city, CDF channel capacity and outage performance.

A. 5G Channel Model of Yogyakarta City

The 5G channel model is a representative PDP calculated from instantaneous PDP generated by NYUSim using a barometric effect. The obtained PDP has the power path beyond -150 dBm. Other powers

below -150 dBm are assumed as noise. The instantaneous PDP is then used to calculate representative PDP. The representative PDP of 5G channel model Yogyakarta under barometric attenuation has 12 paths, both in the minimum barometric and maximum barometric. It is shown in Fig. 4 and Fig. 5.

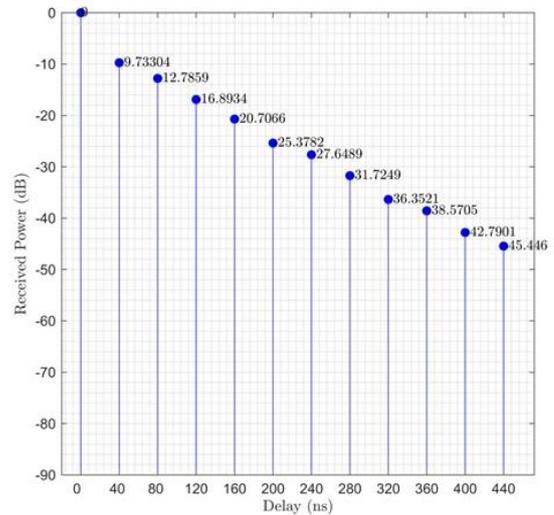


Fig. 4. 5G Channel Model Yogyakarta Representative PDP for Minimum Barometric Pressure.

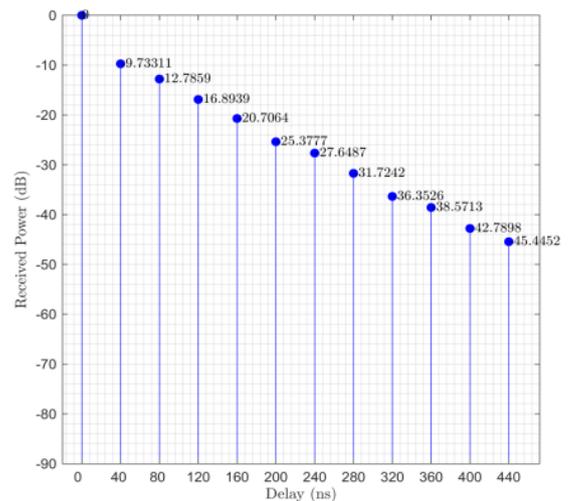


Fig. 5. 5G Channel Model Yogyakarta Representative PDP for Maximum Barometric Pressure.

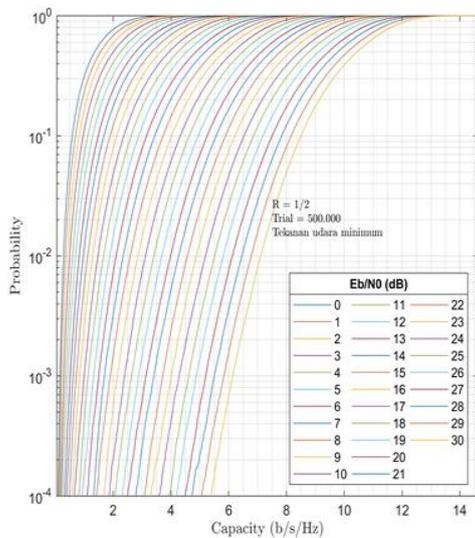
The representative PDP results are then converted from the dB form into numerical form. It will be making it easier to do calculations of finding mean excess delay, mean square delay spread, and root mean square (RMS) delay spread and coherence bandwidth.

B. Cumulative Distribution Function (CDF) Channel Capacity

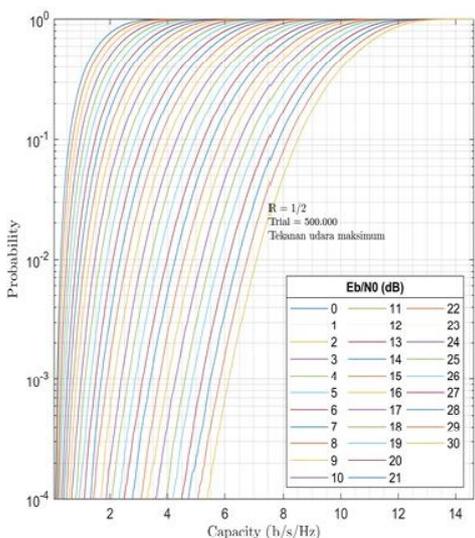
The representative PDP, with the minimum and maximum barometric pressure scenarios obtained in

the simulation, then performs channel capacity calculations. In the calculation of channel capacity, there is a sub-carrier N value of 128. Outage probability is a probability where capacity C falls below the coding rate R using E_b/N_0 0 dB to 30 dB with a channel realization of 500,000 iterations. Furthermore, the channel capacity is processed using CDF to evaluate the value of C and obtain an outage performance graph with $R = 1/2, 3/4, \text{ and } 1$.

An example graphic CDF for $R = 1/2$ can be shown in Fig. 6, while overall CDF value can be shown in Table 2.



(a)



(b)

Fig. 6. An Example CDF of Channel Capacity With $R = 1/2$: (a) Minimum Barometric Pressure, (b) Maximum Barometric Pressure.

Table 2. Example CDF Of Channel Capacity With $R = 1/2$.

E_b/N_0 (dB)	Barometric Minimum	Barometric Maximum
0	0.75799	0.75799
1	0.670286	0.670286
2	0.578544	0.578544
3	0.485374	0.485376
4	0.393046	0.393046
5	0.309312	0.309312
6	0.23221	0.23221
7	0.167368	0.16737
8	0.114052	0.114054
9	0.072842	0.072842
10	0.043916	0.043916
11	0.02468	0.02468
12	0.013	0.013
13	0.00641	0.006408
14	0.002834	0.002834
15	0.00127	0.00127
16	4.54×10^{-4}	4.54×10^{-4}
17	1.84×10^{-4}	1.84×10^{-4}
18	7.20×10^{-5}	7.20×10^{-5}
19	1.80×10^{-5}	1.80×10^{-5}
20	2.00×10^{-6}	2.0×10^{-6}

C. Outage Performance

Outage performance can be analyzed after the channel capacity CDF data results are evaluated, which obtained channel capacity data (C) with E_b/N_0 0 to 30 dB. This paper considers outage probability with $R = 1/2, 3/4, \text{ and } 1$. The outage probability results are expected to be a theoretical reference for 5G system implementation in Yogyakarta.

The outage performance of the 5G channel model of Yogyakarta city is shown in Fig. 7 and 8. The outage performance curve from representative PDP has the same or similar gradient and tendency, indicating that they have the same diversity. Fig. 7 and 8 also show, for example, that the outage probability of 10^{-4} is achieved by the 5G system with $R = 1/2$ in minimum and barometric at E_b/N_0 of 17.6 dB, respectively. Furthermore, the analysis will be explained in section IV.

IV. DISCUSSION

A. The 5G Channel Model of Yogyakarta City

We simulate 1000 instantaneous PDP with maximum and minimum barometric effects from every Rx. The representative PDP of the 5G channel model with a barometric effect has 12 paths. Mean excess delay and RMS delay spread of representative PDP in Fig. 4 and Fig. 5 are 11,407 ns and 31,535 ns. Coherent bandwidth can become an indicator to observe the characteristic of the channel, such that the channel can be classified into frequency flat fading or frequency

selective fading. The coherent bandwidth can be expressed as:

$$B_c = \frac{1}{5\sigma_\tau} \tag{8}$$

with σ_τ is RMS delay spread of the channel. The coherent bandwidth of 5G channel model Yogyakarta with barometric effect in minimum and maximum are 6.34 MHz.

B. Cumulative Distribution Function (CDF) Channel Capacity

Fig. 6 shows the CDF of channel capacity at the condition of $R = \frac{1}{2}$ with $E_b/N_0 = 0$ dB to get channel capacity less than 4.8 b/s/Hz, which shows the probability results of 10^0 or 100 %. While at $E_b/N_0 = 30$ dB to obtain the probability of 100 % shows that the channel capacity is less than 14.6 b/s/Hz. The CDF of channel capacity at the condition of coding rate $\frac{3}{4}$ with $E_b/N_0 0$ dB to get channel capacity less than 5.4 b/s/Hz shows the probability results of 10^0 or 100 %.

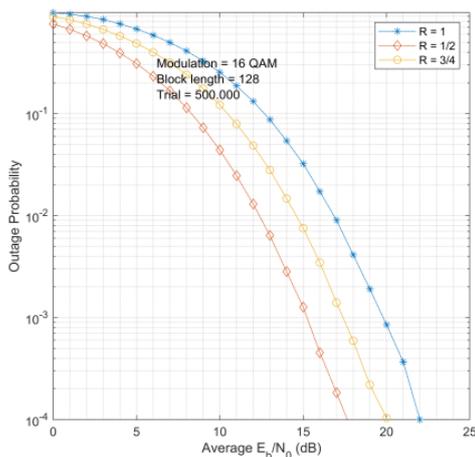


Fig. 7. Outage Performance 10^{-4} (Minimum Barometric Pressure).

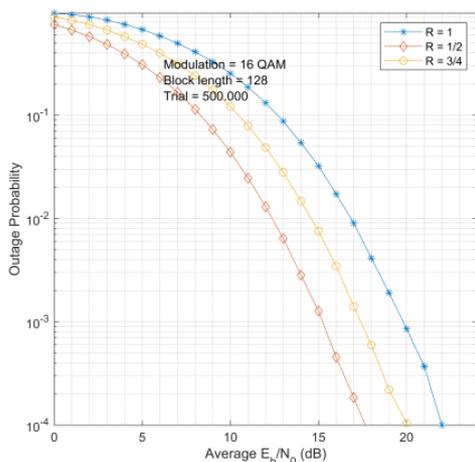


Fig. 8. Outage performance 10^{-4} (Maximum Barometric Pressure).

While at $E_b/N_0 30$ dB to obtain the probability of 100 % shows that the channel capacity is less than 15.2 b/s/Hz. The CDF of channel capacity at the condition of $R = 1$ with $E_b/N_0 = 0$ dB to get channel capacity less than 5.8 b/s/Hz shows the probability results of 10^0 or 100 %. While at $E_b/N_0 = 30$ dB to obtain the probability of 100 % shows that the channel capacity is less than 15.6 b/s/Hz. Considering the results of the CDF channel capacity in the two scenarios, there is no difference in value so that in this condition, the barometric pressure does not affect the channel capacity. The greater the coding rate used in the CDF channel capacity results, the greater the channel capacity value.

C. Outage Performance

The outage probability in the 5G system based on the Yogyakarta city channel model can reach point 10^{-4} (Y-axis), and there is no fluctuation between the outage probability and C . Outage probability point 10^{-4} can be interpreted as a depiction of 10,000 data sent. There is only one failure of sending data (1: 10,000). In both curves, the scenario of minimum and maximum barometric pressure is seen when the $R = \frac{1}{2}$ condition to achieve an outage performance of 10^{-4} requires of E_b/N_0 is 17.649883 dB, $R = \frac{3}{4}$ requires of E_b/N_0 is 20.020953 dB, and $R = 1$ requires of E_b/N_0 is 22 dB. So, it can be concluded for an outage performance graph between the minimum and maximum barometric pressure scenarios, the greater the coding rate used, the higher the power usage (E_b/N_0). The results obtained in the two scenarios are not significant differences, so the barometric pressure in this condition does not significantly affect the outage probability's value. The probability of detection failure (P_{out}) at the coding rate of $\frac{1}{2}$, $\frac{3}{4}$, and 1 is 0.0001 out of 500,000 iterations. So, that as much as 50 channel capacities of C are below the coding rate (R) and the probability of success of detection bits is 0.9999. This shows that there are 499,950 C channel capacities out of 500,000 channel realization values greater than R so that all the bits in the codeword have been successfully decoded.

V. CONCLUSION

Based on the analysis and discussion of 5G channel modeling and blackout performance based on PDP representative with minimum and maximum barometric scenarios derived from environmental parameters of the Yogyakarta city data. The Characteristics Of The Yogyakarta City 5G Channel Model Are Classified As Frequency Selective Fading Because The Value Of Coherence Bandwidth At A Minimum And Maximum Barometric Pressure Is Smaller Than The Transmission Bandwidth (B). The results of cumulative distribution function with minimum and maximum barometric pressure scenarios show probability results of 10^{-4} with $E_b/N_0 = 30$ dB under the $R = \frac{1}{2}$ condition of the resulting channel capacity of 5.4 b/s/Hz, at $R = \frac{3}{4}$ and $R = 1$ the value of capacity canals obtained were 5.9 b/s/Hz and 6.3

b/s/Hz. From these results, there is no difference in the value of the channel capacity between minimum barometric pressure and maximum barometric pressure so that the barometric pressure in this condition is not very influential.

In the curve, both the minimum and maximum barometric pressure scenarios are seen when the $R = \frac{1}{2}$ condition to achieve an outage performance of 10^{-4} shows E_b/N_0 of 17.664883 dB, $R = \frac{3}{4}$ shows E_b/N_0 of 20.020953 dB, and $R = 1$ shows E_b/N_0 of 22 dB. Outage performance results from the two scenarios do not show a significant difference, so that the barometric pressure in this condition is not very influential. Outage performance graph is able to reach a point of outage probability of 10^{-4} , where the greater the coding rate used the results of E_b/N_0 will be even greater.

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