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# Rain Rate Influence on Performance of Semarang 5G-NR Channel Model

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***Abstract*—The demand for higher data rate and large user experience motivates the existence of 5G-NR for twenty-twenty society. However, 5G-NR uses High Frequency, which makes a strong propagation causing lower signal reception due to rain rate in tropical regions. This paper aims to give an overview about the influence of rain rate on the performance of 5G-channel model in terms of Outage Probability and Bit Error Rate. In this paper, we undertook a 5G channel model based on the characteristics of the natural environment of Semarang city, Indonesia. We proposed channel model experiment with series of computer simulations in three criteria: very heavy, moderate and no rain. The data were obtained from Indonesian Agency for Meteorological, Climatological and Geophysics (BMKG) of Semarang City. The results show that the rain rate affects the performance of outage and Bit Error Rate. It is also confirmed by additional information about rain rate attenuation that has the same result: the higher rain rate, the worse the attenuation. However, the most striking result is the influence significance with ANOVA test, which obtain p-value of 1.00. In conclusion, the influence of rain rate on performance of 5G-NR is not significant.**

***Keywords—rain rate influence, 5G-NR channel model, 5G-NR performance, frame error rate, bit error rate***

## I. Introduction

Internet of Things is among the most commonly discussed types of the urges on broadband connectivity and penetration. Besides, the expectation to support 100 billion devices connected to internet network also triggers the development of broadband connectivity. Some factors motivate the situation are the increase in higher demand for higher data rate and large user experience. Larger data rate, larger coverage and throughput can results in better user experience. Data rate increase is in line with communication device growth that resulted in the increase of data traffic [1]. To support these needs, we need a technology that can support large volumes of traffic. This large volume of traffic requires high bandwidth and low latency. The technology that has those characteristics is 5G-NR. 5G-NR (5G-New Radio) has a high bandwidth of up to 100 MHz with very low latency up to 1 ms categorized as excellent so that it can support high traffic volumes and become a support technology for the Twenty-Twenty Society and industrial revolution 4.0 framework such as Internet of Things. Specifically, 5G will become a technology that is standardized for people and things, massive machine connectivity, has a new spectrum band, excels in mobility and security, integration through the internet, processing and storage at network scales and virtualization functional network [2]. 5G technology is estimated to use very high frequencies between 1 GHz - 100 GHz. 5G is expected to be able to overcome problems with coverage, interconnectivity and poor QoS on the 4G technology used on the Internet of Things, begin the use in 2020 and completed in 2030 [3].

Millimeter wave (mmWave) communications have started a new door to the next generation of communication system and become an important part of 5G mobile network in order to provide eMBB services such as VR, AR, and ultra-high definition video (UHDV). However, the blockage of electromagnetic signals is one of the challenges in mmWave communications [4]. Since, the use of very high frequency in 5G typically at 28 GHz and above, makes a strong propagation creating higher attenuation causing lower signal reception, especially due to heavy rain in tropical regions. Rain rate is one of the major causes of obstacles for propagation of mm-waves from the transmitter to the receiver in 5G systems [5]. The theorem asserts that in rainy area, the signals can be absorbed, scattered, depolarized and diffracted by rain [6]. Rain influence becomes more critical when one of which rain rate increase. The effect is more severe in tropical regions, which is known for its high rain rates [7]. Representing the effects of a communication channel through wireless signals is typically performed by channel modelling [8]. Factors are considered in building channel model, such as carrier frequency, bandwidth, the locations of transmitter and receiver. Channel modelling has become a challenge in 5G, because channel modelling influence the system performance. Understanding channel modelling is a principal key to inform the New Radio (NR) specifications and equipment design [9]. Most studies have only focused on the key technologies for 5G such as antenna requirements, architectures and power density [10-12].

Rain attenuation analysis have been conducted in Malaysia with frequency of 26 GHz in terms of prediction and concludes that the rain rate was with the attenuation of 26.2 dB/km [13]. Besides, a rain attenuation prediction also conducted with 28 GHz resulting in 24.949 dB/km and 38 GHz resulting in 35.88 GHz [14]. The flaw of their method have been clearly recognized that this was only done in very heavy rain condition. Few researchers have addressed the issue rain rate influence evaluated from channel modelling with complete criteria of rain rate. Therefore, it is substantial to investigate the performance of 5G-NR with respect to rain rate influence in wider criteria of rain, i.e. very heavy, moderate and no rain. Hence, we conducted a research on rain rate influence in 5G-NR performance analysis by looking at the value of Bit Error Rate (BER) and outage performance. This research was conducted by channel modeling and simulating with input of rain rate, temperature, humidity, and air pressure. The aim of our work was to further broaden current knowledge of rain rate influence to 5G-NR performance in terms of outage and Bit Error Rate performance in a tropical region and categorized as tropical rainforest climate, namely Semarang, Indonesia at the 28 GHz mm-Wave frequency. The method employed channel modelling experiments using NYUSIM (New York University Wireless Simulator) and MATLAB to obtain 5G channel modelling performance. NYUSIM is a channel simulator developed by NYU Wireless and is using numerology of 5G [15]. This paper is organized as follows: Section I is introduction, Section II is the method. Numerical result and discussion are explained in Section III and lastly, Section IV is the conclusion.

## II. Methods

To evaluate the performance, we took first three criteria of rain rate, i.e. very heavy rain, moderate rain and no rain based on the standard of Indonesian Agency for Meteorological, Climatological and Geophysics (BMKG). According to BMKG standard, very heavy rain is classified into rain rate more than 20 mm/h, while moderate rain is classified into 5-10 mm/h [16]. BMKG Semarang kindly provided the real-field environment data of rain rate, temperature, humidity and air pressure in period of January – December 2018. The criterion of very heavy rain mean the value of temperature is taken the lowest, the humidity is taken the highest, the air pressure is taken the lowest and the rain rate was the highest. Moderate rain means the temperature, humidity and air pressure are the average value but the rain rate is taken from the standard of BMKG Indonesia, which is ranging from 5 – 10 mm/h for moderate rain due to rain rate cannot be averaged as what was done to the temperature, humidity and air pressure. No rain is when the rain rate value 0 mm/h, the temperature is taken the highest, the humidity is the lowest and the air pressure is the highest. The reason behind that data retrieval is that these parameters affect attenuation at high frequencies. Rain rate, temperature, air pressure and humidity are interdependent. This is because high rain rate can cause low temperature so that the correlation is negative, which means that when one variable rises, another one falls. High air pressure is associated with dry condition and low pressure is associated with humid conditions. This statement is also reinforced that the characteristics of rain rate are sensitive to temperature in which, when the temperature value increases, the rain rate is low. Once the rain rate data obtained, it is automatically that temperature, humidity and air pressure are also included.

The channel was modelled using numerology 3 with the 28 GHz frequency and 100 MHz bandwidth. The scenario was UMi (Urban Micro) with environment NLOS as well as the lower and upper bound 200 m also Tx Power of 30 dBm and number of RX Locations was 1000. The appropriate delay profile parameter to provide statistical description of multipath delay time is done through one of which is Instantaneous Power Delay Profile (PDP). Propagation of multipath channel causes transmission signal dispersion and disperse level which is expected to be determined through the calculation of Power Delay Profile on a channel [17]. The input value in NYUSIM are shown in Table 1.

TABLE I. Input Parameter Value in NYUSIM

| Criteria | Rain rate (mm/h) | Humidity (%) | Temperature (°C) | Pressure (mbar) |
|---|---|---|---|---|
| Very heavy rain | 42 | 93 | 24.8 | 1005.6 |
| Moderate rain | 8.5 | 77 | 28 | 1009.9 |
| No rain | 0 | 53 | 30.5 | 1014.2 |

The proposed channel model then obtained Power Delay Profile which was spatially averaged to produce Representative PDP as a signal receive power over a multipath channel. Representative PDP value in the 5G channel modelling were converted from dB to numeric or normalized as $E_b/N_0$ value. $E_b/N_0$ is as the normalized SNR and used in analyzing the performance. To quantify the spread of incoming signals, the time dispersion parameter was used. The calculations are Mean Excess delay and RMS (Root Mean Square) delay spread. These two parameters are important in a channel because they are used to describe the temporal dispersive nature of multipath channels. Such the calculations then used to evaluate outage performances validated by Frame Error Rate and Bit Error Rate performance to describe the performance of digital communication system.

We also simulated rain attenuation for each criterion. The steps in rain attenuation includes determination of the rain rate (mm/h) for the time percentage of interest, calculation of specific attenuation of the signal at the rain rate in dB/km as well as estimation of propagation path. So that we could be able to perform rain attenuation, we employed rain rate (mm/h), frequency and path in (m) in the simulation.

## III. Results and Discussion

Rainfall is a natural phenomenon with diverse structure and becomes an important climatic input in the context of climate change. It is noted that rainfall particularly required in radio waves at frequency beyond 10 GHz. The result of outage probability and its validation as well as Bit Error Rate curve in each condition are shown in Figures 1 and 2 with 500,000 iteration. The rate value for all of the performances are equal, namely 1 (uncoded).

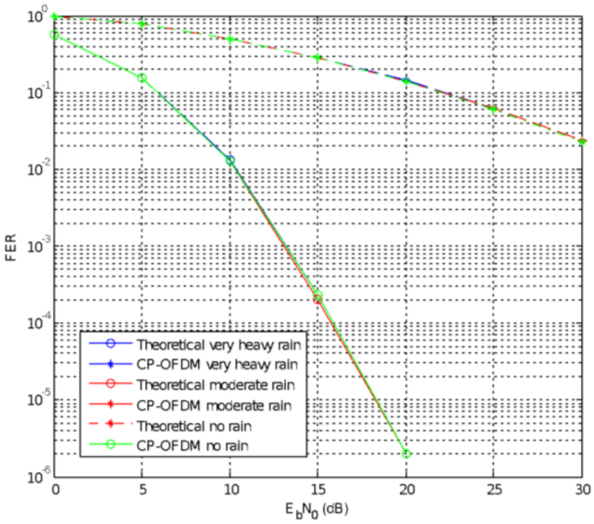


Fig. 1. Outage probability performances validated by Frame Error Rate.

Outage probability is the possibility of information experiencing errors during transmission on the wireless channel, where the message cannot be encoded on the receiver. Figure 1 shows the results of the outage performance validated by Frame Error Rate under R=1. When $E_b/N_0$ is in 10 dB, the outage of very heavy rain is 1.31 x $10^{-2}$, while in moderate rain is 1.28 x $10^{-2}$ and in no rain is 1.31 x $10^{-2}$. To assess whether there is a significant influence of rain rate to performance of outage, an ANOVA test was performed by inserting all the values of outage in each rain rate criterion. Based on calculations, it obtains p-value in 1.00. On combining this result with significance of 0.05, thus p-value is more than 0.05, which means $H_0$ is accepted. Therefore, it comes to conclusion, that there is no significant influence of rain rate on outage performance, thus the effect of rain rate may be ignored.

Subsequent analysis on Frame Error Rate with the value of $E_b/N_0$ in 10 dB show the value in very heavy rain as much as 5.054 x $10^{-1}$ , while in moderate is 5.056 x $10^{-1}$ and in no rain is 5.042 x $10^{-1}$. An ANOVA test was performed and obtain p-value of 1.00, more than 0.05. In conclusion, there is no significant influence of rain rate on Frame Error Rate performance.

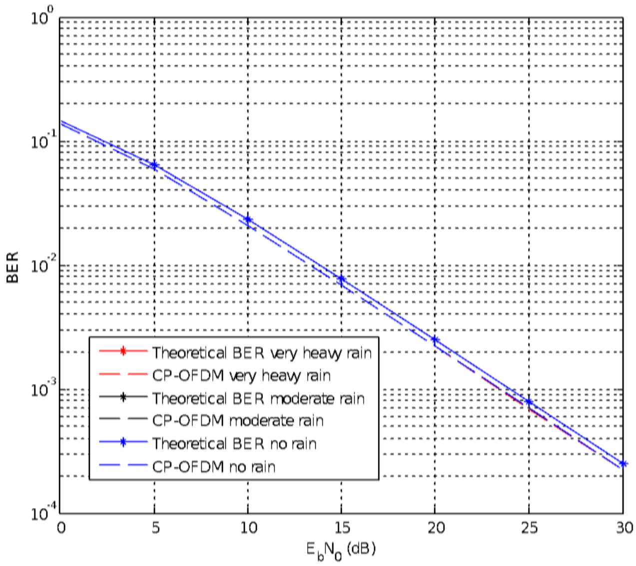


Fig. 2. Bit Error Rate performances.

Figure 2 shows the results of theoretical and CP-OFDM Bit Error Rate under R = 1. In condition where $E_b/N_0$ is 10 dB, the theoretical BER in very heavy rain, moderate and no rain obtain the same value, i.e. 2.33 x $10^{-2}$. Meanwhile at $E_b/N_0$ of 10 dB, CP-OFDM with R=1, the results of very heavy rain, moderate and no rain obtain also the same value, namely 2.10 x $10^{-2}$. Although they have the same Bit Error Rate, however an ANOVA test was done for each criterion, because other dots have different values with slight difference. The results show p-value of 1.00, which means that there is no significant difference of the value. Therefore, there is no significant influence of rain rate on Bit Error Rate performance.

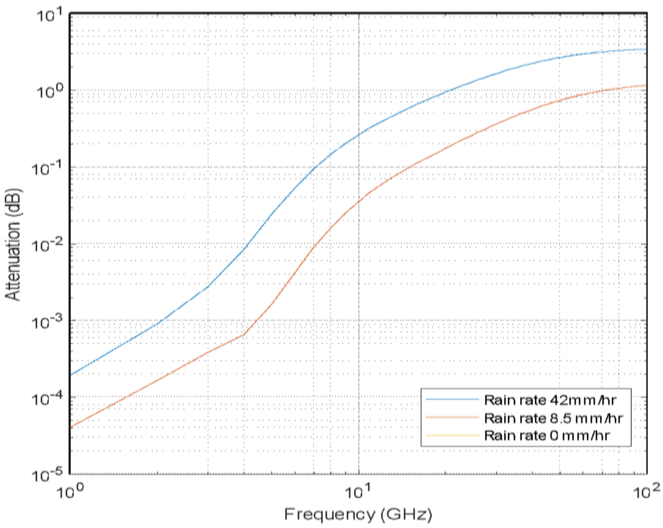


Fig. 3. Rain rate attenuation.

We have presented that the influence of rain rate on performances of 5G-NR does exists, yet not significant. More to confirm that rain rate has influence, we simulated a rain rate attenuation apart from channel modelling. Figure 3 shows the rain rate attenuation at the same frequency, on very heavy rain with 42 mm/h, moderate rain in 8.5 mm/h and no rain with 0 mm/h. The resulting curve indicates that the highest attenuation is at very heavy rain. Whereas on the rain rate curve, the lowest attenuation is obtained when there is no rain so that the rain rate effect curve is not obtained. The reason behind this result is because atmospheric attenuation play roles in which higher rain rate will generate higher atmospheric attenuation. At a frequency of 10 - 300 GHz, wave propagation is influenced by gas attenuation in the atmosphere which is characterized by the dry state of the atmosphere (oxygen) and water vapor. In the troposphere, radio wave propagation experiences signal attenuation or attenuation due to interactions with gaseous components in the transmission line [18]. The contribution from this research is providing the fact that although different rain rate generates different performances of 5G-NR in terms of outage and Bit Error Rate, in fact, proven by ANOVA analysis, the influence is not significant.

## IV. Conclusion

This paper has given an account of rain rate influence in 5G-NR at 28 GHz frequency channel model performances in Semarang city as a tropical region. We have presented the theoretical rain rate influence and proven in simulations based on real-field parameters kindly provided by BMKG Semarang. The results of outage and Bit Error Rate shows the different curves with respect to different rain rate value. In addition, rain rate attenuation curves shows that higher rain rate generates higher attenuation. However, the influence of rain rate to 5G-NR performance, particularly in outage validated by Frame Error Rate and Bit Error Rate is not significant.

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