Barometric Pressure Effect on 5G Channel Model Validated using Convolutional Codes

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Abstract. The fifth telecommunication generation New Radio (5G-NR) is intended to utilize the millimeter wave (mmWave) band, which is sensitive to the natural conditions. 5G-NR requires channel modeling for optimal implementation, particularly for deployment in Indonesia, where the effect of the tropical condition is probably high especially due to the barometric pressure effect. This paper proposes 5G-NR channel model considering natural parameters of Bandung and Palembang, especially in Telkom University (Tel-U) and Universitas Sriwijaya (UnSri) areas, and observes the barometric pressure effects. We evaluate the 5G channel model, where outage performance is validated by frame-error-rate (FER) and bit-error-rate (BER) performances of 5G-NR cyclic prefix orthogonal frequency division multiplexing (CP-OFDM) numerology 2 with convolutional codes. The results show that lower barometric pressure affects on the increase of the number of path of 5G channel model. Outage performance and outage validation of 5G channel model in Tel-U and UnSri area has slightly different result due to barometric pressure effect.

Keywords: 5G-New Radio, Channel model, Channel capacity, Outage performance.

1 Introduction

According the needs of bandwidth, 5G-NR use the available channel in mmWave. The mmWave gives an attenuation caused by the environmental scale that increase the occurrence of blockage and penetration loss is highly dependent on the material [1]. The mmWave candidate for 5G-NR in Indonesia is divide into 3 frequency-band types which are 3.3 GHz, 28 GHz and 33 GHz [2]. But, we predict that 5G-NR will use 28 GHz, in order to give available bandwidth up to 400 MHz and in this working frequency, the attenuation can be tolerate compared to other mmWave that has been trialed measures in 6 GHz - 400 GHz [3][4]. The mmWave have been tried to measure 5G channel model, in example 3GPP, METIS, Quadriga, mmMAGIC [4]-[5] Although these 5G channel modelling are not as good as NYUSIM to analyze channel conditions and spectral efficiency that it is use mathematical propagation approaches of the environment condition [6]. To validate the 5G channel models according to Indonesia's tropical climate, it will be evaluated by measurements of environmental conditions that cause results at New York University Simulation Model (NYUSIM) will be more accurate [7]. The 5G channel modeling research is adopted from a channel modeling exist in Europe and United Stated but they have different environment condition like barometric pressure.
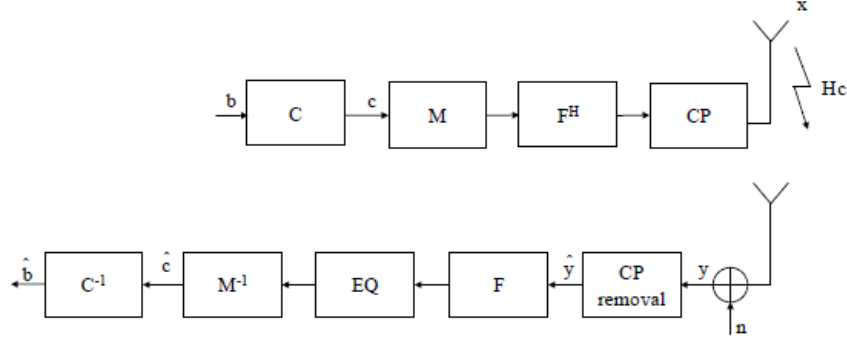
Figure 1. Systems model of to validate the proposed 5G channel model in Tel-U and UnSri area.

This paper proposes Tel-U 5G channel model by considering Indonesia's tropical condition especially barometric pressure that can be generate as representative Indonesia's environment by measure in two cities has different barometric pressure such as Bandung and Palembang city. The 5G-NR channel model is related to research in [8] and [9]. To acquire the 5GNR channel model, which is fundamentally represented in power delay profile (PDP), this paper considers (i) environment conditions estimation of channel modelling, as to adjust the genuine Indonesia's tropical climate and (ii) computer simulations, where NYUSIM is utilized to predict the channel model in Indonesia. The channel model is essential to determine the theoretical outage performance of 5G-NR in Indonesia by expecting Shannon' channel limit is accomplished by convolutional codes.

2 Systems model of proposed 5G channel model

The systems model of proposed 5G channel model is represented in Fig. 1, where **b** is information bits $\mathbf{b} = b_1, b_2, ..., b_k$, **C** is channel coding that using Convolutional codes encoder, **c** is coded bits $\mathbf{c} = c_1, c_2, ..., c_n$, **M** is Complex Binary Phase Shift Keying (C-BPSK) mapper based on [10], $\mathbf{F^H}$ is IFFT block, **CP** is add Cyclic Prefix (CP) for 5G-NR CP-OFDM numerology 2 that we assume CP is longer than PDP length of 5G-NR channel model, **x** is transmitted bits, $\mathbf{H}_c$ are representative PDP of 5G channel model in Tel-U and UnSri area, **y** is received bits, **n** is AWGN, CP removal is remove CP of 5G-NR CP-OFDM numerology 2, **F** is FFT block, **EQ** is equalizer, $\mathbf{M^{-1}}$ is C-BPSK demapper, $\mathbf{C^{-1}}$ is Convolutional codes decoder, $\hat{\mathbf{c}}$ is coded recieved bits $\hat{c} = \{c_1, c_2, ..., c_n\}$, and $\hat{\mathbf{b}}$ is recieved bits $\hat{b} = \{b_1, b_2, ..., b_k\}$.

3 The proposed 5g channel model framework

In this paper, the proposed 5G Channel model focuses on the effect of barometric pressure on Tel-U and UnSri that it will use NYUSIM as tools for simulating the 5G channel model. This work will start by performing real-field measurements based on real environment which is Tel-U with its barometric pressure and the measurement will be also carried out at UnSri as a comparison environment which has barometric pressure.
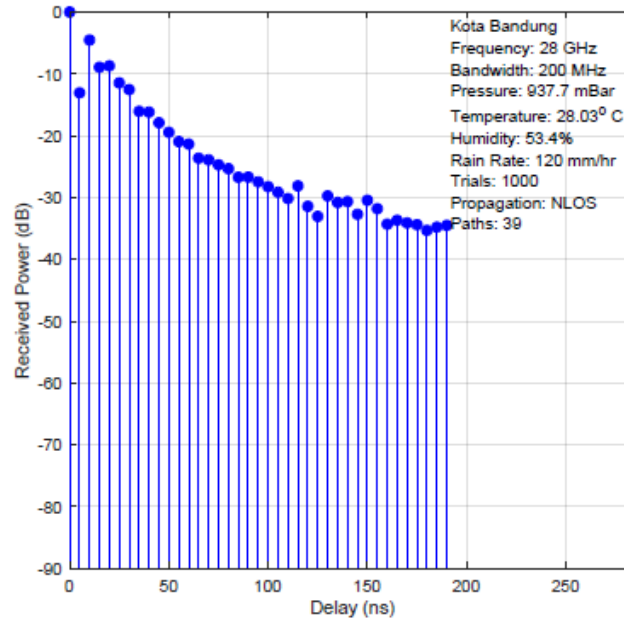
Figure 2. Representative PDP of proposed 5G channel model in Tel-U area.

Next the second step, the computer simulation using NYUSIM will be perform to obtain the PDP for each simulation.

In order to accuracy of the channel, representative PDP of the 5G channel model following steps are adjust the 3GPP standard [11]. Later, with the PDP obtained from previous simulation, we can calculated the value Cumulative Distribution Function (CDF). Every representative PDP construct a circulant matrix of the channel (H_c), by using it we can calculate the outage probability vs SNR as outage performance.

In order to get the accurate measurement of the 5G channel model, outage performance should be validated by set up the agreement in gradients of outage performance, FER and BER of 5G-NR OFDM and convolutional codes. And also, the obtain 5G channel model validated by BER vs SNR performance of 5G-NR OFDM and convolutional codes.

4   The proposed 5g channel model

The proposed 5G channel model is derived based on the representative PDP calculated from a thousand instantaneous PDP with 90 percentile CDF, where the minimum power of path is set to -140 dB before normalized. The instantaneous PDP are obtained using NYU Wireless. Based on the measurement results, Tel-U has environment characteristic of average barometric pressure is 937 mbar, humidity of 53.4 %, temperature of 28.03 (^oC), rain rate $R_{0.01}$ is 120 mm/hr [12]. Meanwhile, in UnSri has environment characteristic of average barometric pressure is 1006.89 mbar, humidity of 46%, temperature of 30.6 (^oC), rain rate $R_{0.01}$ is 132.1 mm/hr [12].

Fig. 2 and Fig. 3 plots representative PDP of proposed 5G channel model in Tel-U and UnSri based on real condition parameter of environment has 39 and 38 paths, respectively.
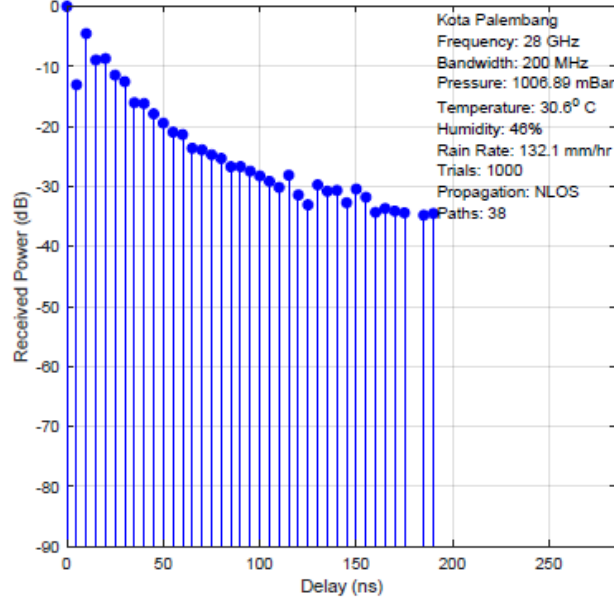

Figure 3. Representative PDP of proposed 5G channel model in UnSri.

5 Performance evaluations of the proposed 5g channel model

The calculation of the capacity needed to avoid inter-symbol-interference (ISI). For multipath fading channels or broadband channel, the expected capacity is expressed as [13]

$$C \approx \frac{B}{N} \sum_{n=1}^{N} log_2(1 + (|\psi_n|^2 \cdot \gamma)). \qquad (1)$$

where N is size of circulant matrix $\mathbf{H}_c$ that equal as a block transmission length of FFT size, γ is the signal-to-noise power ratio (SNR) and ψ is the eigenvalue of multipath channel. 5G-NR channel model obtained to bit rate that reached 20 GBps which can be determined by equation (1) [13]in calculation of the capacity of the channel as

$$C \approx \frac{B}{N} \sum_{n=1}^{N} log_2 \left(\det \left(1 + (|diag[F.H_c.F^H]|^2 \cdot M \cdot R \cdot \frac{N_{FFT}}{N_{FFT}+Q} \frac{E_b}{N_0})) \right) \right). \qquad (2)$$

where B is 200 MHz bandwidth of 5G-NR in 28 GHz, M is 1 bits per simbol of 5G-NR C-BPSK, R is 1/2 coding rate of Convolutional codes, Q is cyclic prefix length of 5G-NR CP-OFDM numerology 2, E_b/N_0 is Energy of the signal divided by noise density and $\mathbf{H}_c$ are representative PDP of 5G channel model in Tel-U and UnSri area, and $\mathbf{N}$ is an IFFT block that adjusts the size of the circulant matrix.

The performance of 5G channel model can be determined by the capacity to evaluate the outage probability. Outage probability indicates the opportunities 5G-NR channel model transmission failure as expressed as [14]

$$P_{outage} = P_r(R > C). \qquad (3)$$

This paper conducts a capacity calculation to observe the CDF of capacity for each representative PDP with barometric pressure effect. We present the outage performance and also outage validation of the proposed 5G channel model with Convolutional codes rates R is 0.5 and
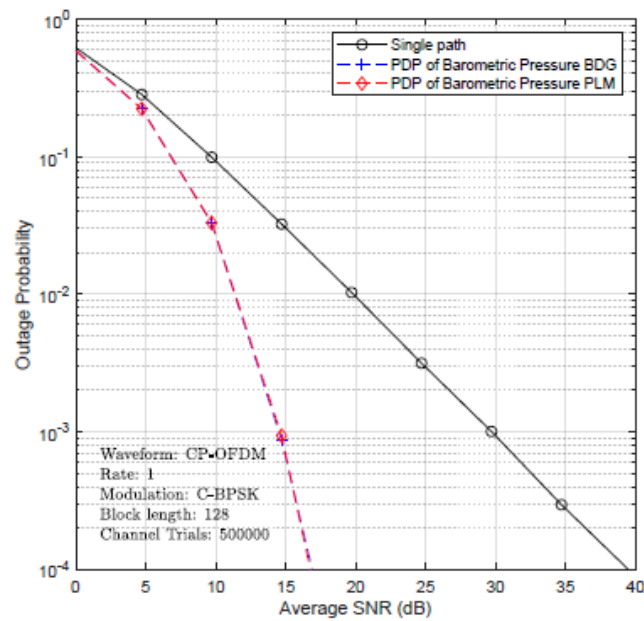

Figure 4. Outage performances of 5G system based on the proposed channel model.

SNR 0 dB until 40 dB as shown in Fig. 4 - Fig. 6. The Outage performances of 5G system based on the proposed channel model at Tel-U and UnSri are plotted by the outage probability toward SNR as shown in Fig. 4. On the same SNR of 14.7 dB, outage performance results are 8.74×10^{-4} and also 9.38×10^{-4}, respectively. The outage probability curve of 5G channel model with lower barometric pressure in Bandung has better performances compared to higher barometric pressure in Palembang. And also, its better performance than single path that the utilization of CP-OFDM with channel coding helps the diversity effect of 5G transmissions to be achieved.

The FER performances for outage performance validation based on the proposed 5G channel model is shown in Fig. 5. There are FER performances gradient difference between Uncoded rate 1 curve and Convolutional codes rate 0.5 curve at 200 MHz bandwidth. It caused the gap between the theoretical outage and uncoded CP-OFDM curve that can be reduced by

utilizing a strong capacity achieve channel coding. On SNR 34.7 dB, the outage validation on 5G channel model in Tel-U and UnSri area by convolutional codes is 4.35×10^{-4} and 4.5×10^{-4}, respectively. On the same SNR, these outage performance and outage validation of 5G channel model in Tel-U and UnSri area has different curve results occurs due to barometric pressure effected.

Fig. 6 shows the BER performance, where the gap between convolutionally coded system and uncoded system under 5G channel model begins with 3.5 dB at BER of 10^{-2}.
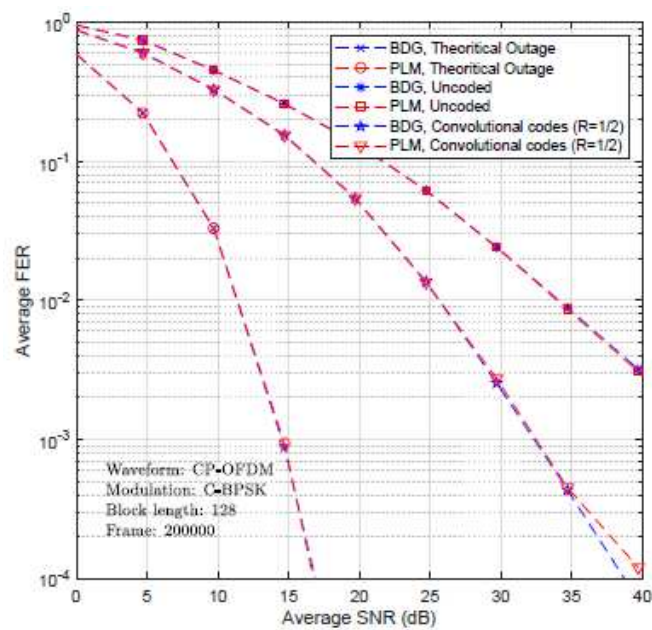

Figure 5. FER performances for outage performance validation based on the proposed 5G channel model.

These validations are provide BER that outage performance has agreement gradient. Furthermore, the outage performance and SNR values are expected to become a reference for 5G system implementation in Tel-U, UnSri and Indonesia.
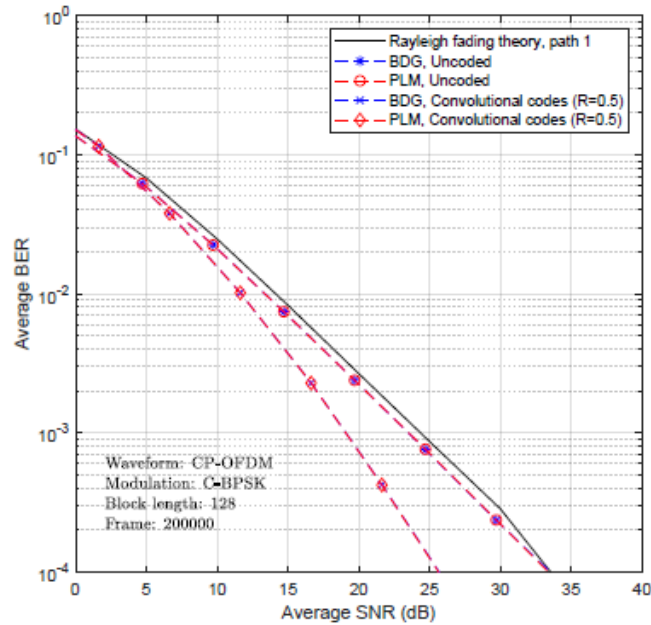
Figure 6. BER performances for outage performance validation based on the proposed 5G channel model.

6 Conclusion

This paper has proposed 5G Channel Model under barometric pressure effect derived for Tel-U and UnSri area, which is validated using BER and FER performances using Convolutional Codes, and 5G-NR CP-OFDM numerology 2 and 5G-NR C-BPSK. This paper has provided 5G Channel Model being specific in Indonesia's tropical climate. The results shows that lower barometric pressure affects on the increase of the number of the PDP path, outage performance and outage validation of 5G channel model in Tel-U and UnSri area.

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