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The effects of rain fade on millimetre wave channel in tropical climate

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Article Info	ABSTRACT
	The main objective of this paper to determine multipath and time-varying channel behaviour of short-terrestrial millimetre-wave point-to-point radio links. In an attempt to invigorate the impact of rain attenuation on mm-wave channel parameters such as the RMS delay spread, path loss received power strength and Rician distribution with a K factor. A brief analysis of rain fading was presented based on the simultaneous measurement of one-minute rain rate and its effects on a short experimental link of 38 GHz. Rain fade average is observed as high as 16 dB for 300 m path at about 125 mm/hr rain intensity. The statistical spatial channel mode (SSCM) simulation software was utilized for an operating frequency of 38 GHz. To generate of power delay profile (PDP). For both omnidirectional and directional antenna. The RMS delay spread and path loss has been estimated using the environmental parameters of Kuala Lumpur city which illustrates the theoretical performances of 5G in Malaysia. It is observed that RMS delay spread, path loss received power strength and K factor effected dramatically by rain fade. (SSCM) simulation software has to be modified to consider rain fade dynamic characteristics to achieve ultra-reliability requirements of outdoor applications in the tropical regions. This study is important for understanding signal propagation phenomena in short distance and enabling the utilization of the millimetre wave band for an urban micro-cellular environment for 5G communication system.

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1. INTRODUCTION

Millimetre wave communication for wideband systems revolutionized the way we live in today's world. It solves the problem of the limited bandwidth with high demand greater data rate for mobile devices [1]. Millimetre wave considered as the extremely high frequency (EHF) with wavelengths ranging from 1 to 100 mm [2]. It has fundamental access to 10 Gbit/s bandwidth with the highest data rates [3]. Hence it is highly recommended for future applications and service such as real-time video streaming and the rise of the Internet-of-Things [4]. It can be utilized to provide high throughput in a small geographic area.

To handling this request, the wireless communication is moving to its (5G) cellular innovation with huge amounts of connected devices. 5G systems have promised an ultra-low latency between 1 ms to 10 ms which offers rise to the best performance [5]. Due to the extremely small wavelength at mm-wave frequencies makes it possible to pack many high gain antennas array on-chip into the mm-wave transceivers. CMOS technology can now operate well into the millimetre wave spectrum in a Cost-effective manner [6].

Millimeter Wave communication systems can employ highly directional antenna using beamforming gain to improve spectral efficiency and reduce the impact of interference [6]. They are characterized by inherent security and privacy because of narrow beam width and limited range. Samsung stated it is 5G system effectively achieving 1Gbps in the 28 GHz band, contrasted with 75 Mbps achieved by (4G LTE) [7]. However, some challenges faced by wideband communications become clear and must be solved [6], [8], [9]. Since each country has different climate parameters, it requires a channel model of 5G developed independently to accomplish the best performances.

Malaysia, characterized by heavy and high rain rates such as a monsoon at a rateof150mm/h with large raindrop sizes. The raindrop size distribution changes according to geographical location, and they can approach the size of radio mm-waves. Hence, due to their comparable sizes, mm-Wave signals are more exposed to blockage by raindrops than signals with longer wavelengths [2]. The mm-wave signals can be absorbed, scattered, depolarized, and diffracted by rain. This can restrict their propagation, causing high signal attenuation loss through effective propagation path length [2], [10]. The level of rain attenuation increases when the rain rate, operating frequency, rain density, or effective length are increased. If the air is not clean, the rain attenuation and atmospheric absorption increase the pathloss and limit the communication range [11, 12]. As such, high rain attenuation of the mm-wave band in tropical regions stand out as a key obstacle facing the implementation of the 5G wireless system.

In millimetre wave networks, a received signal level and interference dynamically vary due to rain attenuation. These physical layer variations have an influence on upper communication layers. Which yields to variable network capabilities to serve traffic demands. Since the designer of 5G communication system looking for 99.999% availability. The rapid channel variation reduces the reliability, availability, and performance of the millimetre wave links [13]. Thus, this paper will examine the impact of rain fade on the millimetre wave channel characteristic parameters such as received power strength, power delay profile and, RMS delay and, coherence bandwidth, and coherence distance. In order to clarify facilitate implementing mm-wave communications for a typical 5G cell size in the tropical region.

Having a good knowledge of the propagation channel characteristics over mm-wave frequencies is considered as a major subject to conduct accurate and reliable 5G communication systems within small cell design. This paper presents wide-band (800-MHz RF bandwidth) propagation under rain conditions at millimetre-wave frequencies over short terrestrial links region tropical in small outdoor cell systems. It has also reported on real measurement data of one-minute rain rate and measured receive signal level simultaneously, in 0.3 km experimental link of 38 GHz. A preliminary analysis on Malaysia 5G channels by utilizing statistical spatial channel mode SSCM simulation software, for an operating frequency of 38 GHz have been presented. The rain impact over the propagation path is analyzed for the average value of rain rate from direct measurement input to NYUSIM software simulation. This model developed in the temperate region New York University [14]. This study can be considered as a portrayal preliminary simulation in Malaysia to investigate the performance of 5G channel during the rainy event. The motivation of this primary study is to investigate challenges and future possibilities in mm-wave applications in tropical areas.

2. MM WAVE PROPAGATION CHARACTERISTICS

Millimetre wave propagation characteristics should be considered for the reliable design of 5G cellular communications. mm-Wave has a higher path loss hence; the coverage will be restricted [15] which make it most appropriate for use in outdoor small cell scenarios and in indoor hotspots [16]. Shadowing impacts and various attenuation losses such as dry air, vapour, haze, and rain of the mm-Wave channel become more challenging at mm-wave frequencies. Millimetre channel characteristic is illustrated in Figure 1. Interference and mobility become more challenge as well as rapid channel fluctuations and intermittent connectivity. As attenuation and atmospheric absorption increase, the path loss limits the coverage [11]. There is a requirement for new knowledge into design and protocols to overcome some impediment such as path loss, higher penetration, precipitation, directivity, foliage losses, sensitivity to blockage. A number of researchers [7], [17], [18] identified some of the essential difficulties and major propagation issues from utilizing mm-Wave for 5G cellular communications and these include:
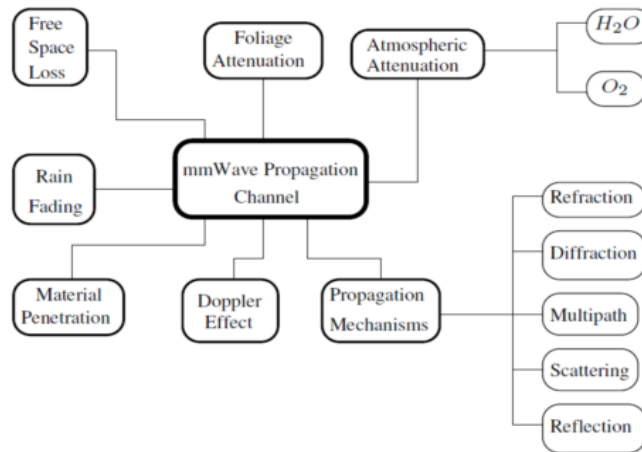
Figure 1. mm Wave propagation characteristics [19]

2.1. Path loss and large-scale fading

Path loss describes the drop-in effective transmit power of wireless signal through the channel, which is determined as [2]:

$$PL\ [dB] = 10\ \log_{10} \frac{P_T}{P_R} \tag{1}$$

Large-Scale Fading characterizes the average received signal strength over the large T-R propagation distance. Path loss could be because of numerous impacts, such as free-space loss, significant diffraction, refraction, coupling loss, and absorption [20].

$$L(d)=P_t+G_t+G_r-P_r(d)-L_0[dB] \tag{2}$$

Gt and Gr indicate TX and RX antenna gains respectively in dBi, and Pt and Pr respectively illustrate, transmitted power and received power in dBm, and L_0 is mm-Wave link loss in dB [21].

2.2. Small-scale fading

Small-scale fading is used to characterize the fast variance of the average received signal strength and phase over a very short distance or period duration as a consequence will complicate the channel impulse response (CIR). There are different models for calculating path loss developed based on experimental data designed to fit a certain scenario or environment [14] such as:
PLCI (f, d) [dB]=FSPL (f,1 m) [dB]+10nlog10 (d)

$$+AT\ [dB]+\chi\sigma\ CI, where\ d \geq 1\ m \tag{3}$$

where the carrier frequency represented as f in GHz, the distance is d, and the path loss exponent (PLE) is n, the attenuation denoted as AT, χσ CI represents a zero-mean Gaussian random variable for standard deviation σ in dB, and the free space path loss is FSPL (f,1 m) in dB at a T-R distance of 1 m.

$$AT\ [dB]=\alpha[dB/m] \times d[m] \tag{4}$$

Where α is the scattering coefficient and the attenuation represents as dB/m for frequency ranging from 1 GHz to 100 GHz [14].

2.3. Blocking

Millimeter wave links are highly vulnerable to both user and environmental mobility. Since mm- wave radios use directional antennas, different obstacles such as high-rise buildings, furniture and human the block the (LOS) signal. In [4] the complex indoor situation, it is likely that the blocked Millimeter wave communication link cannot be restored no matter how the access point and the mobile user change their antenna directions. Most of the connections at 28 GH NLOS, being partly and heavily blocked by high rise buildings, foliage, and vehicular activity [14].

2.4. Millimeter wave human blockage

Blockages of millimeter-wave communication attenuation by human greatly affect link performance. A model has been presented to investigate the impact of human blockage at 73 GHz link [22]. The research found that a person could induce more than 40 dB of loss when standing 0.5 m from the TX antenna or the RX antenna, with a signal decay rate of 0.4 dB/ms at walking speeds. Hence, human blockage is a big issue yet to be fully modeled.

2.5. Considerations on spatial consistency

Spatial consistency can impact so many aspects of 5G system evaluations. It should be considered as an essential feature in channel modelling rather than an optional one, in the high-frequency channel modelling study item [23].

2.6. Penetration and other losses

The penetration loss is considering one of the most major challenges in implementing 5G cellular communication at mm-wave frequencies. During the communication, signals penetrate through the walls and this will produce a very high penetration loss and causes system performance degradation. It is found that the penetration loss quality is lower for dry walls and clear glass at 28 GHz link. In contrast, it is high for brick and tinted glass with about 28 dB and40 dB for 28 GHz signals [24]. The result of an intensive study at 28 GHz indicates that the penetration loss is around 26.5 dB for a concrete wall of 40 cm thickness, while it is higher than 40 dB at 60 GHz signals for the same concrete wall. The previous study mentioned that 28 GHz is more favorable for mobile communications, particularly in Non-Line of Sight (NLOS) environment [25].

Doppler effect in wireless communication leads to change in the received signal frequency due to motion between transmitter and receiver. Fundamentally line-of-sight (LOS)causes degradation of the link performance [19].

2.7. Link budget of 5G signal

Link budget of 5G signal consider all effects of mm-wave propagation which, depending on the frequency and scenarios of interest represented. In the example below: Received power in dBm=Tx power+Tx antenna gain+Rx antenna gain–path loss–rain fade (est. 2dB/200m)-shadowing loss (20 to 30dB)–foliage loss (10 to 50dB)–atmosphere absorption–terrain/humility-Fresnel blockage-system margin. Fresnel zone radius (R)=17.32 x √(d/4f) (d in km, f in GHz). By examining the above equations, it is obvious that many factors can cripple mm-Wave links. The link budget is the most important area of focus for any 5G deployment team.

3. RMS DELAY SPREAD

The Root Mean Square (RMS) delay spread (ɕRMS) is a parameter that characterizes the propagation delays of a channel. This is an important result that has implications on the data rates that can be transmitted through these channels. RMS is useful in estimating if the channel will cause inter-symbol interference without the use of an equalizer. Generally, given (ɕ_RMS), it is requiring (ɕ_RMS/Ts) symbols to be equalized to remove the inter-symbol interference effect for symbol rate 1 Ts. Thus, it has to consider the root mean square delay spread RMS [26, 27]. It is the most commonly used one for measuring the delay time. BER is dependent on the RMS delay spread as well. The cyclic prefix in OFDM system is typically determined by maximum excess delay or by the RMS delay spread of the environment. The RMS delay spread can be expressed as:

$$\tau_{RMS} = \sqrt{\int_0^\infty \frac{(\tau-\tau')^2 p(\tau)\,d\tau}{\int_0^\infty p(\tau)\,d\tau}} \qquad (5)$$

Where is $p(\tau)$ the power delay profile of the channel, τ' is the average delay of the channel.

4. THE RICAN K-FACTOR

The distribution of the short-term received signal envelope after propagating different paths can be described by a-Rice distribution [26]. The Rican K-factor specifies the ratio of the strongest multipath power Pmax to the sum of powers of the other weaker multipath, as in the equation below:

$$K = \frac{P_{max}}{P_{tot-P_{max}}} \qquad (6)$$

Where P_{tot} is the total received power from all multipath components (e.g. area under the PDP curve). The K-factors were computed to determine whether strong multipath components exist in LOS and NLOS environments [28, 29]. In LOS environments, this will be the ratio of the power of the first arriving multipath component to the sum of powers of all later arriving multipath components. This was suggested by industry users. There is a strong relationship between the rain rate and k factor:

$$K = 16.88 - 0.04RdB \hspace{3cm} (7)$$

Relationship between the Rician factor (dB) and rain rate (mm/h) as (7). (7) shows that the factor is proportional (with a negative sign) to rain rate [28]. In this paper, the Ricean K-factor has been calculated for every PDP and is an output parameter in the data file for each simulation run to investigate the impact of tropical rainfall characteristics in this important parameter in mm-wave channel.

5. RAIN-INDUCED FADING

Millimetre-wave transmission can encounter critical attenuation during heavy rain [30]. At 25 mm/h rain rate can introduce attenuation more than 10 dB/km a range of frequencies 60 to 73 GHz. Rain attenuation even reaches up to 30 dB/km if the rain rate reaches 100 mm/h in tropical regions [31]. Recent studies in outdoor urban-microcell (UMi) propagation at millimetre-wave showed that future cell radii of cellular communication will be 200 m [31]. Hence at such short path length, atmospheric and rain attenuations can be ignored [12]. However, most of these measurements were implemented in temperate regions. On the other hand, in different tropical areas with consistent and heavy rainfall, rain attenuation impact cannot be discounted even for this small cell size. It emerges as a key impediment facing the implementation of the next generation of smartphones. Thus, extensive research on channel characterization during rainfall is required to develop an accurate rain fade prediction for a wide range of mm-Wave frequency bands [12]. Rain rate and rain fade based on real measurement data implemented in Malaysia at 38 GHz with 300 m TX to RX separation distance at LOS environment have been reported in order to explore the effects on mm-wave bands in outdoor activities for 5G systems in tropical regions. The specification of the link illustrated in Table 1 and Figure 2.

Table 1. Measured link specification

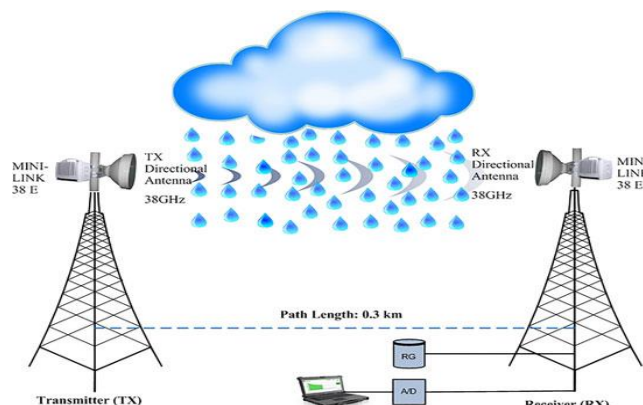| Frequency Band (GHz)	37.0-39.5 GHz	
Polarization	Horizontal	
Maximum Tx Power dBm	+15.0	
Receive Threshold (dBm)	-79.0	
Tx & Rx Antennas	Gain (dBi) 44.9	Size 0.6 m
Antenna beam width	10∘	
Link bath length	300m	

Figure 2. The radio link system configuration based on MINI-Link 38 E unit [31]

The rain rate and received signal strength data were periodically monitored and logged daily for every minute during rainy events, in 24 hours via the data logger for fifteen months from Jan 1999 to Mar 2000. The collected data were analyzed with developing MATLAB software code to obtain the average yearly rain

attenuation and rain rate [1]. Existing rain fade prediction models are based on path reduction factors techniques. This approach used with link typically more than 1.0 km. The path reduction factor is assumed to approximately equal to 1 for shorter link lengths (typically less than 1.0 km) because rain rate would be uniform along the path [32], [33]. ITU-R 530-17 prediction model [32] has been used to compare measured and predicted values of rain fade. Direct original measurement has given an average value of 125 mm/h at 0.01 % of time rain rate exceeded [1].

5.1. Rain attenuation measurements at 38 GHz

The equivalent, path attenuation along LOS a 300m link for horizontally polarized was calculated by the difference between the RSL during clear sky conditions and the RSL during rain. That is,

$$\text{Attenuation} = \text{RSL}_{\text{clear sky}} - \text{RSL}_{\text{rainy}} \tag{8}$$

Moreover, the increase of mm-wave signal attenuation due to rain was measured with reverence to free space path loss. In free space, the received signal power P_r via an unobstructed LOS path with no multipath components is given by:

$$Pr(dBm) = Pt + GT + GR - 20\log_{10}\frac{(4\times\pi\times d)}{\lambda} - PL\ (\text{rain}) \tag{9}$$

Where P_t transmitted power; G_T transmitter gains; G_R receiver gains λ wavelength; Lpath length. (9) and has been used to measure attenuation due to rain as well. Moreover, rainfall rate measurements data R has been converted into an equivalent value of rain attenuation A_R along the path of the 300-m link using the power-law approximation:

$$A_R \frac{KR^\propto}{1000} \times 300 \left(\frac{dB}{m}\right) \tag{10}$$

Parameters k and α depend on frequency, rain temperature, and polarization; and their values can be obtained from ITU-R P.838-3 [34]. The worst two rainy events, individually, in February have been plotted in Figure 3 with measured rain rate data and measured receive signal level for the same period. The results presented in Figure 3 indicates that received signal strength has been sharply decreased by around 22dB during the heavy rainfall event on 16/02/2000, 6.6 dB/m.
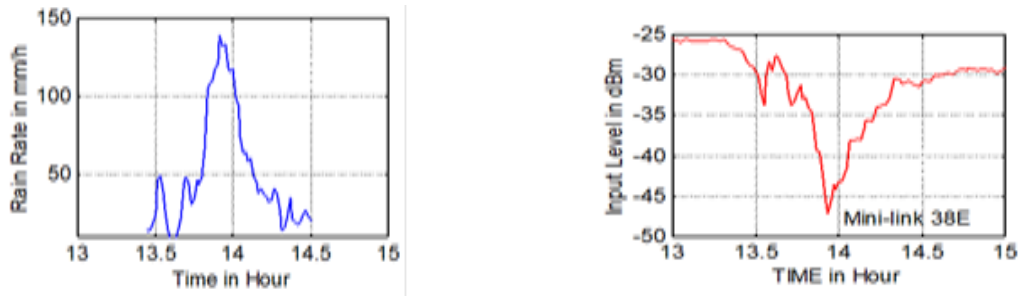

Figure 3. Measured rain rate and the corresponding received signal strength on experimental Mini-links at 38 GHz operating in Malaysia

In Table 2, recorded absolute path loss & rain attenuation values at 38 GHz for horizontal polarization by link, measurement date, and weather condition. Figure 4 and 5 present the differences between signal attenuation on a clear sky and signal attenuation on rainy events. On a clear day, the signal received is above the attenuation threshold, -25.5 dB. This weather, the mm-wave link not recorded any outage due to rain attenuation. But on the rainy weather the signal received at the receiver is below the attenuation threshold, -25.5 dB. This happens due to the interference caused by raindrops and mm-wave signal travelling through the atmosphere. When this phenomenon occurs, the transmission is weakened by scattering more than the absorption of the signal by raindrops. Hence, the number of multipath components will increase. As a result, the 5G systems that operate during this duration will experience an outage due to rain attenuation and difficult to achieve ultra reliability requirements of outdoor applications at tropical regions. Thus, the use of suitable beamforming access techniques will be needed to maintain the ultra-reliable system operation.
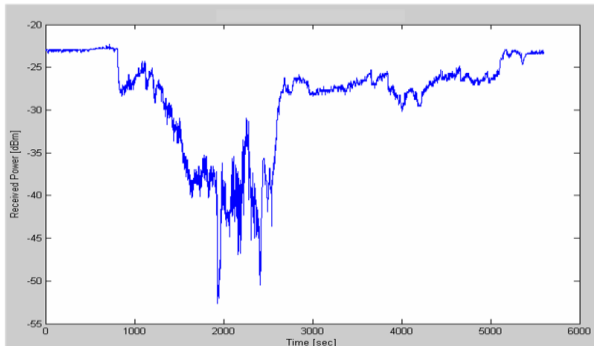
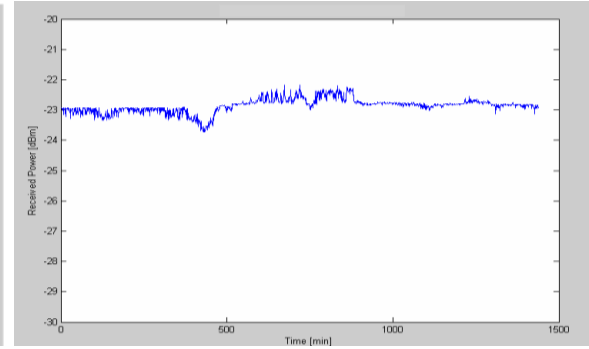Figure 4. Received Signal level time series during rain events

Figure 5. Received Signal level time series during clear-sky

Table 2. Absolute path loss & rain attenuation values at 38 GHz. 23/2/2000 from 17:8 to 17:23pm

LOS Rain Attenuation Measurements at 38 GHz (Horizontal Polarization) and (300 meter LOS Millimeter wave-Link		
Rain rate mm/h	Path loss in dB	Rain attenuation in dB
30	104.08	6.72
30	105.42	8.06
30	104.90	7.545
30	105.88	8.52
60	107.15	9.79
60	108.63	11.27
60	108.87	11.51
60	110.21	12.85
90	111.55	14.20
120	108.33	10.97
90	112.90	15.54
120	112.18	14.71
120	115.59	18.23
150	114.05	16.68
90	108.17	10.81

The path loss rain rate and rain fade values, shown in Table 2, illustrate a clear trend. At lower rain rates, total path signal attenuation experienced by the propagating millimetre wave is comparatively small. With an increase in rain rate, the dropping level in received signal strength (RSS) increases linearly. It's observed that the received signal fluctuations increase rapidly during rainy events. The path loss exponent is an experimental constant that is often measured, however, can as well be derived theoretically in some environments. From the data measured results, it was 3.28 during rain and proximity 2 at clear sky weather. It differs depending on the millimetre wave signal propagation environment and describes, the rate at which path loss rises with Tx to RX separation distance for a given propagation environment.

5.2. Comparison with rain models

In this section, the rain attenuation values, calculated from data files, are compared with rain models described in Section 5.1. For a given short path between the transmitting and receiving antennas, compares the rain attenuation values in Table 2, measured for horizontal polarization configuration, with corresponding values predicted by the ITU-R 530-2017 attenuation model for different rain rates. the measured and predicted attenuation is compared at0.1 % %, 0.01 % and 0.001of the time, as follows. The average value of measured rain fade is 4.71 dB, 10.84 dB and 16.25 dB, whereas the ITU-R predicted values are 3.8 dB, 8.5 dB and 11.6 dB, respectively. It's clear that ITU-R model underestimates rain attenuation in the tropical climate [35-39]. Thus, more accurate prediction models for short mm-wave terrestrial ink are needed. A preliminary analysis of Malaysia 5G channels by utilizing statistical spatial channel mode SSCM simulation software, for an operating frequency of 38 GHz have been presented. The rain impact over the propagation path is analyzed for the average value of rain rate from direct measurement input to NYUSIM software simulation [1]. This model developed in the temperate region of New York University. It's found that NYUSIM main code considers Law and Parsons Rainfall DSD Model.

The Laws and Parsons model has been shown to be more suitable for temperate regions and not an accurate model for rainfall DSD estimation for regions outside Europe and North America. As well as in 3GPP channel model have used ITU-R model. Thus, it considers not accurate to investigate the performance of 5G

channel during the rainy event in the tropical climate. Since the designer of 5G communication system looking for 99.999% availability [1]. According to the above results, it is recommended to propose and develop an efficient prediction model to investigate the worst-case scenarios that will be more accurate for cellular communications services in tropical regions. Rapid channel fluctuations and intermittent connectivity considered one of the key challenges in understanding the implementation of cellular communications in the mm-wave band [3]. It is obvious to say that during the rain event the fluctuation of amplitude and phase on mm-wave signal have been increased. This will impact the dynamic channel impulse response. As well as al small-scale parameters of the channel expected to change at heavy rain events. This physical layer fluctuation produces an impact on upper layers of the communication system, which leads to variable system capacities and instability to serve data rate request [5]. Therefore, in design mm-wave communication systems at 38 GHz, the analysis of the statistical and dynamic behaviour of rain fading must be investigated thoroughly.

5.3. Millimeter wave terrestrial link availability

Availability, which refers to the system constancy against possible outage scenarios. It's defined as the probability that a given service is available (i.e., coverage). Which denote the presence or absence of link reliability. Hence, availability reflected the link reliability. It is affected by path loss, shadowing, rain fade, and other large-scale parameters of the channel. Availability of a service is a geographic characteristic, which varies from place to place, and potentially on long time scales, e.g., related to hardware failures [5]. According to the average measured rain fade at 38 GHz around 16 dB, the probability that the attenuation of the channel is wares than 16dB calculated was 0.02455. In Termes of rain fade, the availability of millimetre-wave link depends on the probability of occurrence of heavy rain to cause an outage. The percentage availability of mm-wave link is tied to the rainfall characteristic of the location where the link is deployed, as well as the path length. In this case, the availability can be presented as:

$$Availability = 100\% - outage \tag{11}$$

6.   ANALYSIS IN MALAYSIAN TROPICAL CLIMATE STATISTICAL CHANNEL MODELS

In this paper, we considered Kuala Lumpur city climate parameters, which is in the tropical region with high rain rate, large raindrop sizes and strong thunderstorms over the year. Considering a bandwidth of 800 MHz with a carrier frequency of 38 GHz for 5G in outdoor, we investigate the performance of the channel in an urban microcell (UMi). The signal propagation, both LOS were conditioned at 300m T-R separation distance. The directional and omnidirectional receiver (RX) antennas were utilized [1]. The average value of rain rate, humidity, temperature, and barometric pressure as climate parameters obtained from real measurements are shown in Table 3 as input to NYUSIM software simulation [14]. Where delay profile PDP was generated to estimate the number of multipath components above the noise threshold, the power of the LOS component, the absolute propagation time, path loss due to atmospheric attenuation and multipath scattering, path loss exponent and RMS delay spread. Statistical results are outlined in the next sections.

Table 3. Input channel parameter to the NYUSIM of Kuala Lumpur City represent of 5G Malaysia

Input Channel Parameters	Value(s)
Frequency	38 GHz
Channel bandwidth	800 MHz
Condition	UMi
Environment	LOS
TX-RX separation distance	300m
TX Power	15 dBm
Barometric Air Pressure	1010.00 mbar
Humidity	85%
Average Temperature	28∘C
Average Rain Rate	125mm/hr
Foliage Loss	0.4dB

Generated PDP's are classified by links Tx to Rx separation distance, and weather condition summarized in Table 3. A comparison of the PDP's under various weather conditions is given in Figures 6, 7, 8, 9. Xu et al showed that multipath could occur at the edges of very intense and compact rain cells. Pressure, temperature, and rain could change the refractivity of the atmosphere, thus creating fluctuating propagation paths and propagation delays. It's observed that rms delay was higher in case of omnidirectional transmission, while it was lower at the directional antenna. Results show that, with considering rain, the RMS delay spread can be as high as 21.9 ns on the omnidirectional antenna LOS path, and 6.5 ns on the directional antenna. The

difference in rms delay was 4ns and 3.6 ns between clear sky and rain in omnidirectional and directional antenna respectively. The scattered power and the delay spread are larger for omnidirectional antennas. It's worthy to mention that directional antennas boost the received power and coherence bandwidth (BC). This is because when directional antennas are used, most of the reflectors and scatterers will fall outside the antennas beam width [3]. It is inversely proportional with τ_RMS [Bc $\alpha 1/\tau$_RMS] BC parameter represents delay spread in the frequency domain. which quantizes the frequency differences of the wireless channel.

The minimum received power of each multipath component) determined by the transmit power, dynamic range (DR) of simulation system (190 dB) and a 10 dB SNR, dynamic range maximum possible omnidirectional path loss in dB, according to T-R separation distance. If T-R separation distance is no larger than 500 m, then set dynamic range as 180 dB, otherwise set it to 220 dB threshold Th equals the transmit power in logarithmic scale minus 180 dB [14].

$$Th=TX\ Power–DR \tag{12}$$

The Ricean K-factor has been calculated for every PDP and is an output parameter in the data file for each simulation run. It was -5.568 in case of rain condition while it recorded -2.076 at clear sky weather. Ricean K-factor decreases with increasing rain rate due to increase power of the reflected multipath components [26]. The result showed a decrease in the LOS power as the multipath power increases during rain. (7), combined with the received total power estimate, provides a powerful tool to model received signal variation and the resultant outage probability for mm-wave systems

Data files created from NYUSIM can be utilized to simulate CIRs for mm-Wave systems. The omnidirectional path loss is found lower than directional path loss in scenarios LOS .It was close to measured values than directional antenna scenario. However real measurement of shadow fading and path loss exponent are also needed. It is found that received power decreased by 6.4 dB in Malaysia link compared with a link at temperate region because of path loss was higher at 38 GHz when taking rain fade into consideration. It is observed that the path loss difference because of other weather parameters (humidity, temperature, and barometric pressure) only influence the link by increasing path loss by 0.1 dB.
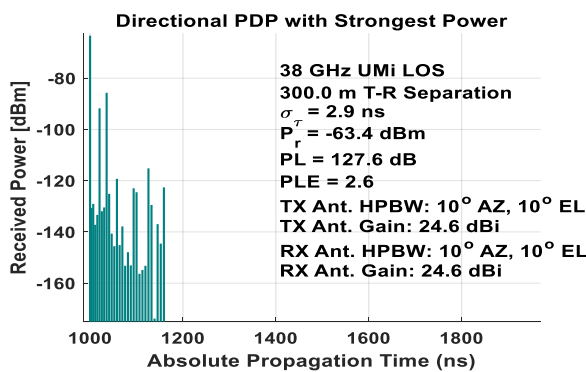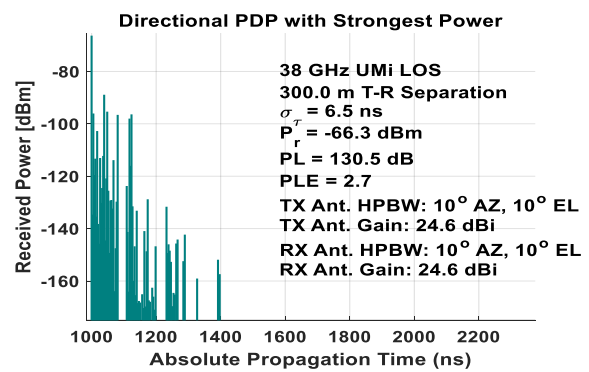

Figure 6. Directional LOS-PDP with at clear sky
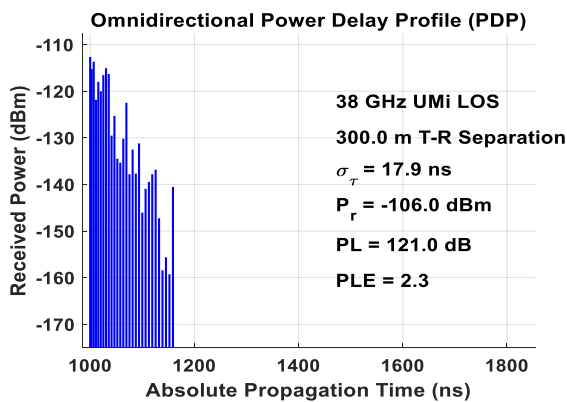

Figure 7. Directional LOS-PDP R=125 mm/h

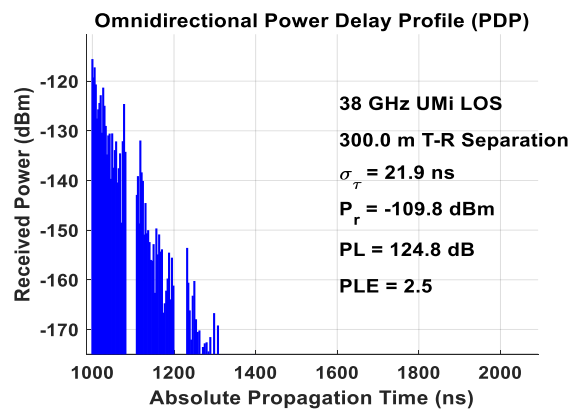
Figure 8. Omnidirectional LOS-PDP at R=0 mm/h

Figure 9. Omnidirectional LOS-PDP at R=125 mm/h

7.   CONCLUSION

Millimetre wave communication provides high capacity and data speed. In this paper, an overview of the challenges faced by mm-wave that support wideband communications is provided. Major propagation issues from utilizing mm-Wave for 5G cellular communications include path loss, penetration loss, rain fade, blockage, doppler, and multipath. Human blockage is found a big issue yet to be fully understood and modelled. Furthermore, spatial consistency also remains to be investigated and modelled. The main limits of the existing channel models are lack of measurements on bandwidth, spatial characteristics for dual mobility, directional antennas and large-scale antennas for massive MIMO. The main purpose of this paper was to study the impacts of various weather events such as rain on the behaviour of the broadband millimetre-wave channel in tropical area. Averaged attenuation in a Malaysia was measured to be 16 dB over the 300 m path. These allow the designer to define the additional fade margin needed for ultra-reliable operation of broadband communication systems at millimetre-wave frequencies. The preliminary result of Malaysian 5G channels by utilizing statistical spatial channel mode SSCM simulation software for an operating frequency of 38 GHz have been presented. The average value of rain rate, humidity, temperature, and barometric pressure as climate parameters obtained from real measurements in Kuala Lumpur are used as input to NYUSIM software simulation. Multipath statistics shows that while very few multipath components were detected in clear, dry weather, more multipath components were detected during rain. that cussed variation in small scale channel parameters such as RMS delay spread, path loss, path loss exponent and k factor. It is also found that received power decreased by 6.4 dB on the link in Malaysia compared with a link at temperate region because of path loss was higher at 38 GHz when taking rain fade into consideration. It is observed that RMS delay spread effected dramatically by rain fade. This study shows that further investigation is required to model 5G channels in tropical areas.

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