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# UWB CHANNEL CHARACTERIZATION IN 28 GHZ MILLIMETER WAVEBAND FOR 5G CELLULAR NETWORKS

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Ahmed M. Al-Samman*, Tharek A. Rahman, Razali Ngah

Wireless Communication Centre, Universiti Teknologi Malaysia, 81310 81310 UTM Johor Bahru, Johor, Malaysia

*Corresponding author
Ahmedsecure99@gmail.com

## Abstract

The demands of high data rate transmission for future wireless communication technologies are increasing rapidly. The current bands for cellular network will not be able to satisfy these requirements. The millimeter wave (mm-wave) bands are the candidate bands for the future cellular networks. The 28 GHz band is the strongest candidate for 5G cellular networks. The large bandwidth at this band is one of the main parameters that make the mm-wave bands promising candidate for the future cellular networks. To know the wideband channel behavior in mm-wave bands, the wideband channel characterizations are required. In this paper, the 3D WINNER model is used to model the wideband channel at 28 GHz band. Based on this model, the time dispersion parameters at 28 GHz mm-wave band are investigated. The root mean square delay spread and the mean excess delay are the main parameters that can be used to characterize the wideband channel. Morever, the cumulative distribution function (CDF) is used to model the RMS delay spreads. The results show that the RMS delay spread varies between 4.1 ns and 443.7 ns.

*Keywords*: UWB channel, mm-wave, 5G, RMS delay spread, WINNER model



## 1.0 INTRODUCTION

The demand for high data rate communication in cellular networks is increasing rapidly. For example, the universal mobile telecommunication system (UMTS) predicts that the mobile traffic will rise above 800 Mb/subcarrier daily by 2020 [1]. To fulfill these demands, a new wireless technology is required that can offer orders of magnitude increase in cellular capacity. The high capacity requires more bandwidth, high signal-to-noise ratio (SNR) and increasing in the number of antennas.

In lower bands below 6 GHz, the capacity is increased by using some techniques. In long term evolution advanced (LTE-A), the capacity is increased by adding more bandwidth using carrier aggregation technique [2]. The maximum bandwidth that can be achieved by carrier aggregation is 100 MHz which is, not enough for the 4G cellular capacity requirements. To achieve the required capacity for 4G cellular network, the multiple-inputs multiple-output (MIMO) technique has been used. In LTE-A, up to 8×8 MIMO for downlink transmission and 4×4 for uplink transmission is used [3]. However, taking into consideration the additional traffic of cellular networks beyond 2020 as predicted by UMTS, future cellular networks may need to deliver as much as 1000 times the capacity relative to current levels. Likewise, as expected, the wireless connectivity will not be limited to smart phones and tablets but it will be used by many new devices perhaps up to 50 billon devices will be connected by 2020 [4], [5]. The congestion in the current cellular band (below 6 GHz) reduces the ability of using it to achieve the future requirements for very high broadband multimedia communication in different devices. The millimeter wave (mm-wave) bands above 6 GHz are the main candidates for the next generation cellular network

(5G cellular system) where more bandwidths are available up to 10 times of today's cellular networks [6]. The 28 GHz band has been studied as one of the mm-wave candidate bands for 5G cellular networks [7–9].

In 28 GHz freuency band, various of channel measurements have been done at the New York University (NYU) campus in downtown Manhattan in a wide range of urban environments [10–12]. A 400 megachip-per-second (Mcps) sliding correlator channel sounder was used to conduct these measurements. The 800 MHz first null-to-null radio frequency (RF) bandwidth has been used for high temporal resolution [8]. Based on this bandwidth, the channel in mm-wave 28 GHz band for 5G cellular can be classified as the ultra-wideband (UWB) channel since any channel that has an absolute bandwidth of 500 MHz or more is a UWB channel [13]. In 5G cellular networks, the channel should be a UWB channel to provide a high cellular capacity. The UWB channel can be characterized by two main parameters; root mean square (RMS) delay spread and mean excess delay. The analysis of these parameters provides knowledge of the channel behavior that can be exploited in any adaptive wireless communication technique [14,15]. The RMS delay spread has been investigated for mm-wave band in indoor environments at 60 GHz [16–18]. For the 28 GHz band, the RMS delay spread has been analyzed based on Local Multipoint Distribution System (LMDS) measurements [19]. However, few studies have investigated the RMS delay spread analysis and model in the urban environments at 28 GHz band for small cell [11,20].

As the 28 GHz mm-wave band is still under experiments for the future cellular networks (5G cellular system), to the best of our knowledge, the channel models for mm-wave band at 28 GHz have been investigated only in narrowband [6]. In [6], they developed the statistical models for the cluster power fraction and angular characteristics based on NYU measurements [11]. In the current cellular bands, different models have been proposed for narrowband and wideband channel model [21–24]. In wideband channel model the maximum bandwidth that has been used in LTE-A system is 100 MHz which is very low as compared to the required bandwidth for the 5G cellular system. This means that the channel in 4G cellular systems can be classified as wideband channel but the channel in 5G cellular systems is an UWB channel. So, the time dispersion parameters for mm-wave band cellular networks are the crucial part for wideband channel model at 28 GHz due to the high bandwidth. Many of current models that can be developed for 5G cellular network have been stated in [25]. The Wireless World Initiative for New Radio (WINNER) model [22,23] and the European Cooperation in Science and Technology (COST 2100) model [24] are the responsible tools for different studies because of their scalability and acceptable complexity. The WINNER model [22] is based on a 2-D modelling approach. An extension of the WINNER II/+ models was introduced by Stephan, *et al.* [26] under the acronym "QuaDRiGa"—Quasi Deterministic Radio Channel Generator. It is a 3D model and it has geometric polarization. Also, it can be used for satellite and terrestrial communications. Furthermore, it can support the continuous time evolution for transmitter-receiver (TX-RX) links with a single base station with environment transitions and both large and small-scale fading between segments.

Although the standardization of 5G stills under studies, according to academic and industrial research, vendors are intensively contributing in 5G development with an essence concentrate on the technology include new spectrum bands air interface, new transmission schemes, spectrum aggregation, massive MIMO, beamforming, D2D (Device to Device) communications and self-backhauling, among others. The 5G wireless networks are expected to utilize the microwave range above 6 GHz and mm-wave bands. Therefore, different models still under studies because the standard frequencies for 5G has not been assigned yet.

In this paper, the 3D WINNER propagation model has been used based on modifying the parameters that can be used with 28 GHz mm-wave band in outdoor densely urban environment. The scenario in this paper emulates the 28 GHz channel measurements in NYU campus in downtown Manhattan in a wide range of urban environments [11]. The time dispersion parameters are investigated based on this model. The ability of using 3D WINNER propagation model to investigate the wideband channel model can be investigated by comparing the simulated time dispersion parameters with the measurement results that are extracted from NYU propagation measurements.

The rest of this paper is organized as follows. In Section 2, the model of the channel is described. The time dispersion parameters are discussed in Section 3. The results and discussion are presented in Section 4. Section 5 concludes the paper.

## 2.0 CHANNEL MODEL DESCRIPTION

The parameters used in the WINNER model for mm-wave band is shown in Table 1. These parameters are used in NYU measurement [8]. In [6], the path loss model parameters are calculated based on NYU measurement.

The scenario in this model emulates the 28 GHz NYU measurements. The height of the TX is chosen to be 17 m and the RX was placed 86 m away from the TX at the start location, which is used as the reference distance. The TX position is fixed, which represents a base station, while the RX has been represented in the model by different locations as a number of segments as shown in Figure 1.

**Table 1** Simulation Parameters

| Variables | Parameters Value |
|---|---|
| Carrier Frequency | 28 GHz |
| RF Bandwidth | 800 MHz |
| Cell Size (m) | 200 |
| Path Loss Model (log-dist) | A=2.1, B=61.4 |

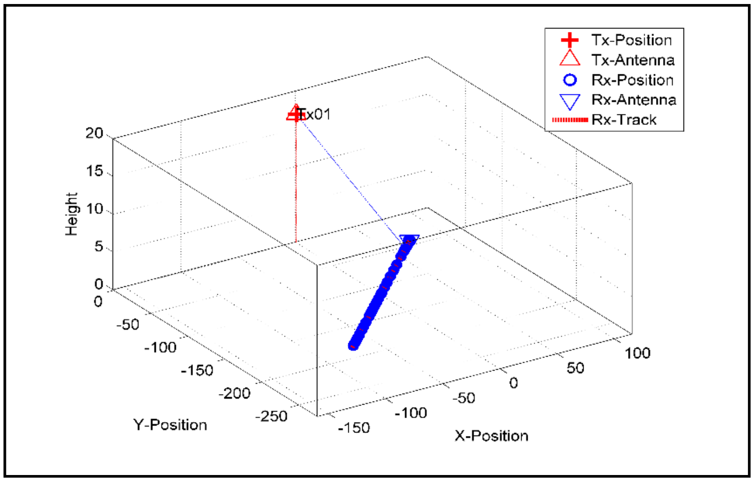


**Figure 1** Scenario for the simulation model

Moreover, each snapshot in this scenario was taken per meter till the cell size which is chosen 200 m. The channel impulse responses (CIRs) are extracted from channel coefficients by 1024-point IFFT with a sampling period Ts = 1 ns. The 20 dB threshold has been used above the thermal noise to reduce and eliminate the noise effects.

The conventional model for UWB channel is given as [27]:

$$h_\tau = \sum_{l=0}^{L-1} \alpha_l \delta(\tau - \tau_l), \quad (1)$$

where $\alpha_l$ and $\tau_l$ are the *l*-th path gain and delay, respectively, *L* is the maximum channel delay and $\delta$ is the Dirac delta function. In this paper, we can model the channel, based on the scenario described in Figure 1, as:

$$h(p) = \sum_{l=0}^{L-1} \alpha_l(p)\delta(\tau - \tau_l(p)), \quad (2)$$

where *p* is the location index of transmitter or receiver movement, depending on which one is moved, whereby the channel is captured

## 3.0 WIDEBAND CHANNEL PARAMETERS

The wideband channel characteristics can be defined by many parameters such as the number of multipath components, mean excess delay and RMS delay spread. The time dispersion parameters are mainly characterized by two parameters; the RMS delay spread and the mean excess delay. The RMS delay spread can be defined by the second order statistical model of power delay profile as [28]:

$$\tau_{rms} = \sqrt{\overline{\tau^2} - \left(\overline{\tau_m}\right)^2}, \quad (3)$$

where $\overline{\tau^2}$ is the second moment of the PDP and it is given as:

$$\overline{\tau^2} = \frac{\sum_k p(\tau_k)\cdot(\tau_k)^2}{\sum_k p(\tau_k)} \quad (4)$$

and $\overline{\tau_m}$ is the mean excess delay, also given as:

$$\overline{\tau_m} = \frac{\sum_k p(\tau_k)\cdot\tau_k}{\sum_k p(\tau_k)}, \quad (5)$$

where *p* and $\tau$ defined as the power and delay of the *k*-th path, respectively.

## 4.0 RESULTS AND DISCUSSION

In this section, the wideband channel characteristics results are presented. The RMS delay spread variation with TX-RX separation distance is shown in Figure 2.

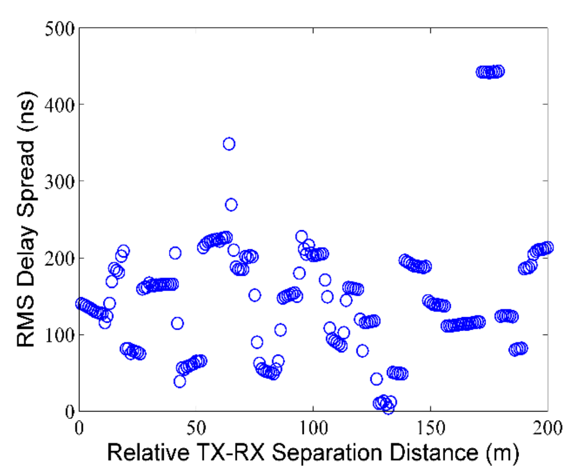


**Figure 2** RMS Delay Spread versus TX-RX Separation Distance

The RMS delay spread values increase as the TX-RX separation distance is increased. However, the relation is not linear because some of positions of the receiver that have a longer separation distance provide the lower RMS delay spread than the shorter distance. This implies that some of multipath components at the particular long distance may either disappear or reach the receiver faster. The RMS delay spread values varies between 4.1 ns and 443.7 ns and the average value is 151.1 ns.

The cumulative distribution function (CDF) has been used to model the RMS delay spread based on different distributions, Lognormal, Nakagami, Rician and Weibull distributions as shown in Figure 3. The Log Likelihood test is used to identify the distribution which best represented the RMS delay spread after estimating the maximum likelihood of the distribution parameters. It can be shown that all used distributions are fitted the RMS delay spreads. This implies that the RMS delay spread can models by using any of these distributions. The Weibull distribution is the best one can be used to model the RMS delay spread.

The mean excess delay values versus TX-RX separation distance is shown in Figure 4. It is in the range of 243-785.9 ns where the maximum value is at 190 m separation distance and the minimum value is at 46 m separation distance. The ratio of mean excess delay to the RMS delay spread indicates that the amount of dispersion for the received signal. From these results, it shows that the ratio is varies between 1.8-59.3. The large values of this ratio imply high concentration of power at large excess delay. In other words, the dispersion of the channel in emulated scenario is high.

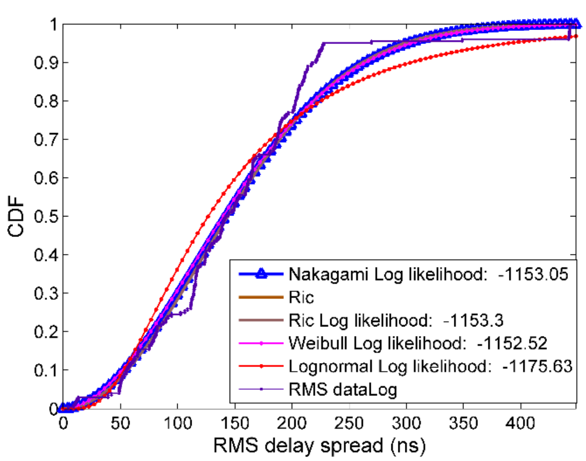


**Figure 3** Cumulative Distribution Function for RMS Delay Spread

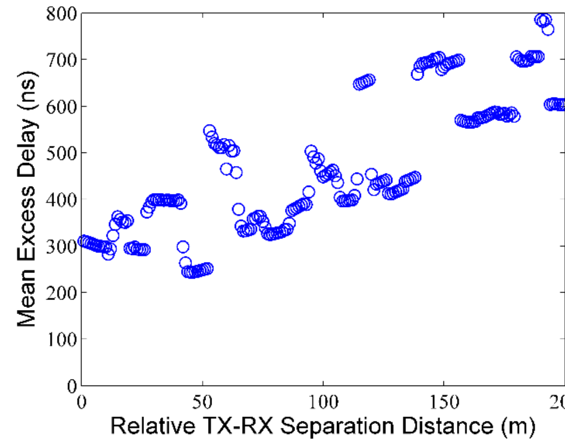


**Figure 4** Mean Excess delay versus TX-RX Separation Distance

## 5.0 CONCLUSION

In this paper, the wideband channel characteristics have been presented. The 3D WINNER model has been modified by using 28 GHz parameters. The modification of model emulated the small size of cell (200 m) that is used as access point for 5G network. The time dispersion parameters are estimated based on this model. The maximum RMS delay spread, mean excess delay are 443.7 and 785.9 respectively. The findings are reported that the emulated channel has high time dispersion. The CDF is used to model RMS delay spread values. The Weibull model is the best fitting to model the RMS delay spread. In Future work, the measurements will conduct in different frequencies of mm-wave band to provide the best candidate of frequencies for 5G wireless networks.

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