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# Analysis on Wideband Channel Model for High Speed Wireless Communication Systems

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***Abstract*—The paper emphasizes on the analysis on wideband channel model for high speed wireless communication systems. The research problem in this study are based on the following concepts such as (i) Firstly, it is necessary to change to the appropriate physical devices that can support 5G system, (ii) It is required to design a channel that will adapt to the medium that will be convenient for the changed physical devices, and (iii) Mobile terminals that currently use 4G cannot be used in 5G system. The objectives in this study are - to analyze the existing channel model for mobile communication, to analyze the mathematical and dynamical model for wireless propagation channel, to implement the wireless propagation channel with specific purposes, to implement the optimized channel model performance, and to evaluate the performance of the developed channel design. The numerical analyses in this study are conducted by using MATLAB language. The research direction in this study are based on the channel system functions, and tapped delay-line models. The simulation results are confirmed that the 12 taps in this study for the high speed wireless communication system design.**

***Index Terms*—Channel Modelling, High Speed Wireless Communication Systems, Numerical Analysis, Performance Accuracy, Tapped Delay-Line Model, Wide Band Channel**

## I. INTRODUCTION

TIME dispersion translates, in the frequency domain, to non-uniform filtering of the transmitted signal, i.e., a non-ideal response, meaning a non-flat magnitude and nonlinear phase.

Those responses will vary in time: a frequency-selective fading channel. The wideband condition is a relative one that depends on the transmitted signal bandwidth. Anti-multipath techniques such as equalization, multi-carrier orthogonal frequency-division multiplexing (OFDM) or code division multiple access, direct sequence-spread spectrum (CDMA DS-SS) may be used to counter these effects [1-3].

Issues relative to channel simulation, including the time-varying tapped delay-line (TDL) model, are very important to understand. This is practically equivalent to studying the channel effects on signals with narrow bandwidths. However, it is very important to quantify the effect of the channel on any kind of transmitted signal, i.e., signals that occupy a wide range of possible bandwidths [4-6].

As the frequency separation increases, the fading behavior at one of the frequencies tends to be uncorrelated with respect to the other. This is due to the fact that the electric lengths will be significantly different. The correlation between the behavior at these two frequencies will depend on the time spreading caused by the environment (dispersion of path lengths and associated powers). Thus, signals occupying larger bandwidths will be distorted. This phenomenon is known as frequency selective fading, which means that there is a nonuniform frequency response throughout the transmitted bandwidth. The minimum bandwidth for which selective fading effects start to be observed is known as the channel's coherence bandwidth [7-10].

Channel models are required for simulating propagation in a reproducible and cost-effective way, and are used to accurately design and compare radio air interfaces and system deployment. Common wireless channel model parameters include carrier frequency, bandwidth, 2-D or 3-D distance between transmitter (TX) and receiver (RX), environmental effects, and other requirements needed to build globally standardized equipment and systems. The definitive challenge for a 5G channel model is to provide a fundamental physical basis, while being flexible and accurate, especially across a wide frequency range such as 3–300 GHz [11-13].

The paper is organized as follows. Section II presented the channel system functions. Section III mentioned the tapped delay-line model. Section IV expressed the results and discussions. Section V concludes the study.

## II. CHANNEL SYSTEM FUNCTIONS

The time-domain description of a linear system is specified by its impulse response. Since the channel is time-variant, the impulse response is also a time-varying function. If the lowpass equivalent, time-varying impulse response is h(t,τ), where τ is the delay variable, then the complex envelope at the receive side, y(t), is related to the input, x(t), by a convolution integral, i.e.

$$y(t) = \int_{-\infty}^{\infty} x(t-\tau)h(t,\tau)d\tau \quad (1)$$

where the time variations are contained in the fluctuations of h(t,τ). The convolution can be rewritten as a summation, i.e.,

$$y(t) = \Delta t \sum_{m=1}^{n} x(t-m\Delta t)h(t,m\Delta t) \quad (2)$$

This expression provides a physical representation (Fig.1(a)) of the channel in the form of a dense tapped delay-line (TDL) composed of differential delay elements and modulators [1].

The channel can also be represented by another function, H(f,v), dual of h(t,τ), which links the output to the input

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spectra, i.e.

$$Y(f) = \int_{-\infty}^{\infty} X(f - v)H(f - v, v)dv \quad (3)$$

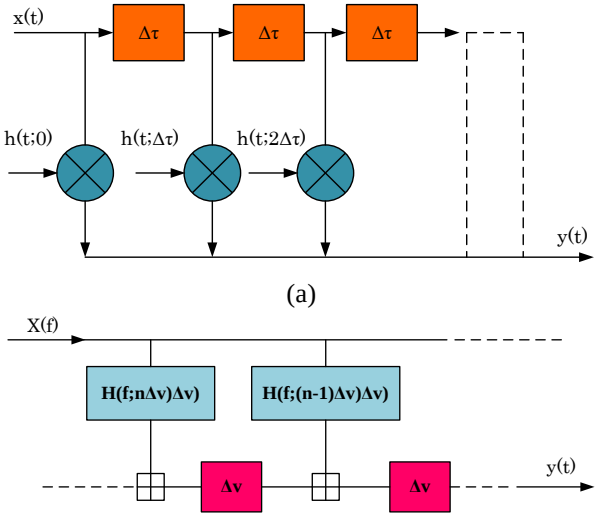



**Fig. 1.** (a) Dense TDL channel representation. (b) Channel representation in the frequency domain

Again, the equation can be written as a summation,

$$Y(f) = \Delta v \sum_{m=1}^{n} X(f - m\Delta v)H(f - m\Delta v, m\Delta v) \quad (4)$$

This function allows a further physical representation of the channel in the form of a dense frequency conversion chain, analogous to a TDL, consisting of a bank of filters with transfer functions, H(f,v)Δv, followed by Doppler shifting frequency converters, producing Doppler shifts in the range (v,v+Δv) Hz (Fig.1(b)).

## III. Tapped Delay-Line Models

Both the channel and the transmitted signal must be represented in the discrete-time domain in order to carry out simulations. The channel effects can be introduced in this discrete-time framework using a tapped delay-line (TDL) model.

The sampling rate, fs, must account for the maximum Doppler, and take into account the signal bandwidth, B. Thus, the required sampling frequency is $f_s \geq 2(B+f_D)$. The discrete-time channel model assumed is a transversal or FIR filter with time-varying taps, $g_i(t)$, spaced $\Delta\tau = t_s$ (Fig.2).

If the WSSUS assumption is made (Section 7.4), the complex coefficients, $g_i(t)$, are uncorrelated, and Gaussian distributed (central limit theorem). This model is a direct representation of the joint delay-Doppler probability distribution, $p(\tau,n)$, which is proportional to the scattering function, $R_S(\tau,v)$. In the TDL model, this joint probability density function is given in the form.

$$p(t, v) = p(t)\, p(v|t) \quad (5)$$

i.e., the channel is modeled in terms of the power-delay distribution, $p(\tau)$, and of the Doppler distribution conditioned to each specific delay, $p(v|t)$.

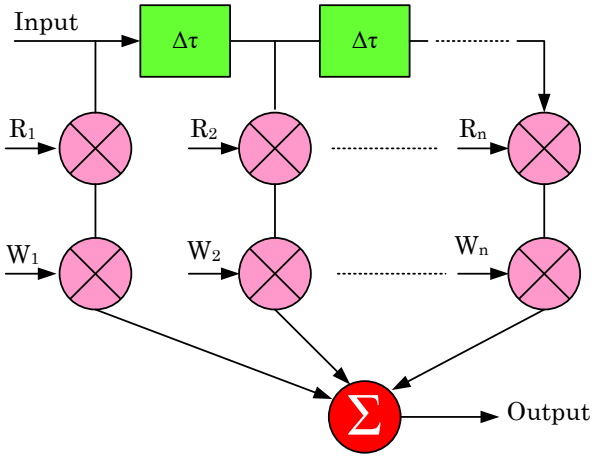



**Fig. 2.** TDL model representing a time-varying channel

## IV. Results and Discussions

Fig.3 illustrates the distribution of powers associated to each the tap. Fig.4(a) and (b) show the definition of the Gaussian filter in the time and frequency domains.

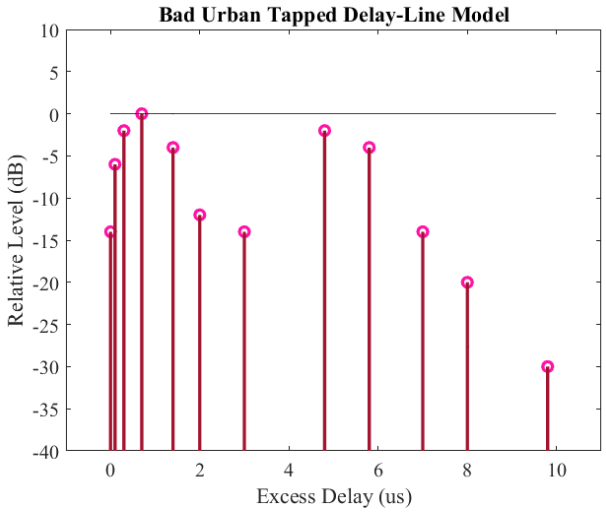
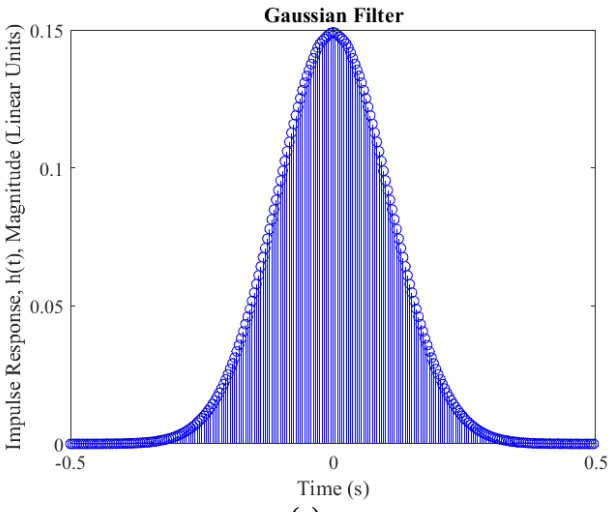
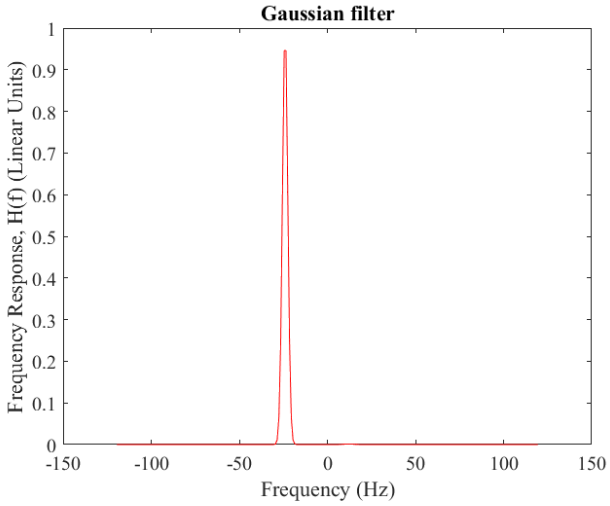



**Fig. 3.** Relative powers for all 12 taps



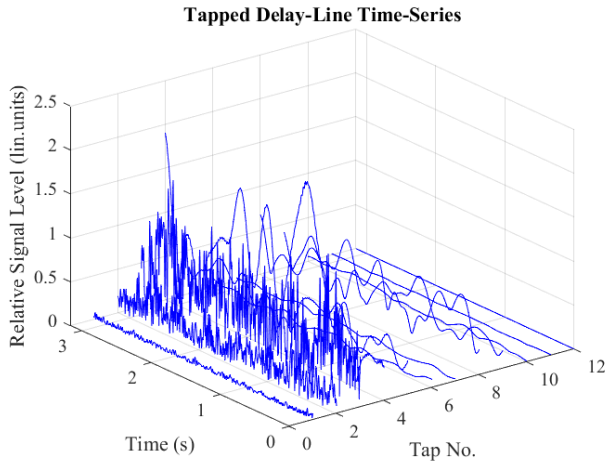

(a)



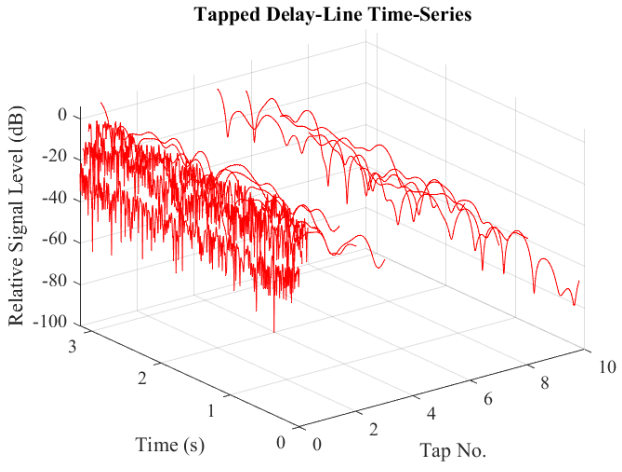

(b)

**Fig. 4.** (a) Frequency domain representation of one of the Doppler Gaussian filters. (b) Discrete time-domain representation of one of the Doppler Gaussian filters

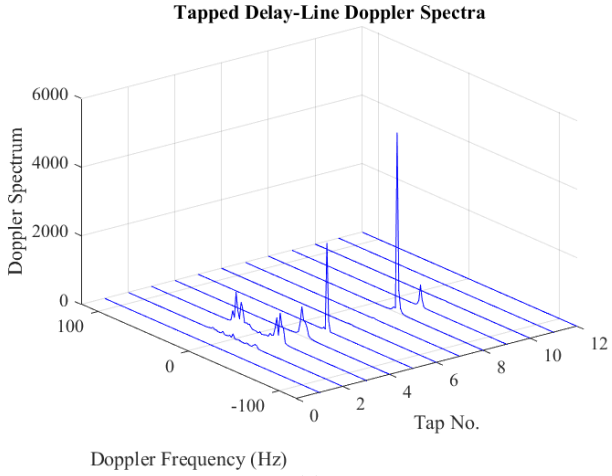
Finally, Fig.5(a), (b) and (c) illustrate the time series of the magnitudes and corresponding Doppler spectra for all the taps. When the time spreading introduced by the channel is significant with respect to the duration of the transmitted symbols, selective fading starts to be meaningful.




(a)




(b)




(c)

**Fig. 5.** (a) and (b) Time series for all 12 taps. (c) Doppler spectra for all 12 taps

The techniques for characterizing wideband channels, starting with deterministic time-varying channels, and then going on to introduce the stochastic characterization have been evaluated. The wideband channel in the frame of the multiple point-scattered model, which has been used for presenting illustrative channel simulations is analyzed.

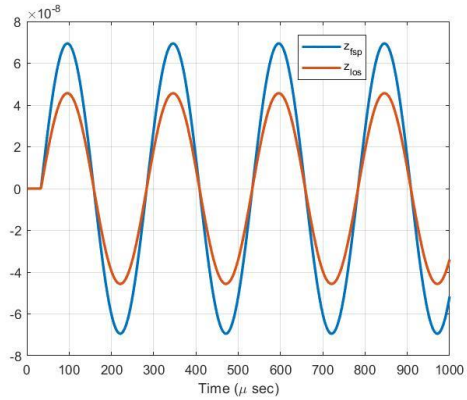



**Fig. 6.** Line of Sight Propagation Channel Model

The propagation model in the LOS channel includes free-space attenuation in addition to attenuation due to atmospheric. The signal output for free space model and line of sight model are very similar but the different amplitude in reality. The free space model is ideal in practical applications. Fig.6 illustrates the Line of Sight Propagation Channel Model

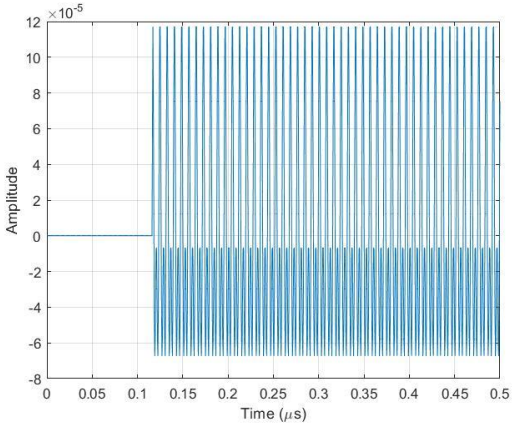



**Fig. 7.** Wideband LOS Channel Model (Signal Input)

This model the propagation of wideband electromagnetic signals through a line-of-sight (LOS) channel from a source to a destination. In an LOS channel, propagation paths are straight lines from point to point. The propagation model in the LOS channel includes free-space attenuation in addition to attenuation due to atmospheric gases, rain, fog, and clouds. Fig.7 demonstrates the Wideband LOS Channel Model (Signal Input)

The comparison between free space signal and line of sight signal could be observed according to the transmitted and received antennas systems. The propagation models in free space and line of sight could be emphasized on the wideband electromagnetic signals. The system could be applied range-dependent time delays to the signals, as well as gains or losses. When either the source or destination is moving, the system object applies Doppler shifts.

## V. PERFORMANCE METRICS

### *A. Bit Error Rate Analysis*

The Bit Error Rate analyses based on Signal-to-Noise Ratio are completed with theoretical, AWGN Channel and the Wide Band Channel Model. According to the performance comparison among those three conditions, the proposed wide band channel model meets the performance specification in high speed telecommunication system design. Fig.8 mentions the Bit Error Rate Comparison among theoretical, AWGN Channel Model and Wide Band Channel Model.

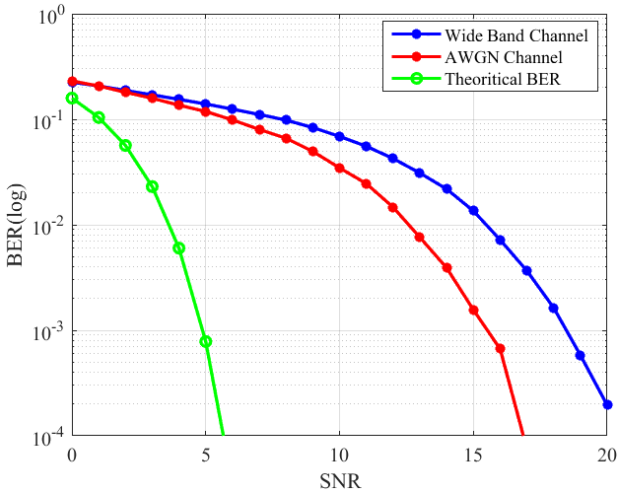



**Fig. 8.** Bit Error Rate Comparison among theoretical, AWGN Channel Model and Wide Band Channel Model

### *B. MIMO Capacity Analysis*

MIMO Capacity with different Transmitters and Receivers with Wide Band Channel Model was analyzed. The channel capacity depends on the number of transmitted and received antenna systems. The MIMO channel capacity will be increase when the SNR values are increase. If the number of transmitted and receiving antennas are four and above, the MIMO capacity will be higher and the performance specifications in high speed telecommunication system design will be achieved. Fig.9 illustrates the MIMO Capacity with different transmitters and receivers with Wide Band Channel Model. The Wide Band Channel Model has various performance accuracy for signal receiving for the practical applications and the latency analysis could be observed in the nest section.

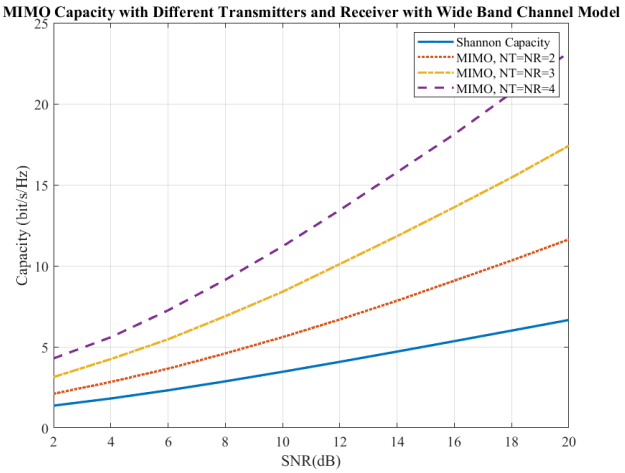



**Fig. 9.** MIMO Capacity with different transmitters and receivers with Wide Band Channel Model

### *C. Latency Analysis*

While the attenuation models for atmospheric gases and rain are valid for electromagnetic signals in the frequency range 1–1000 GHz only, the attenuation model for fog and clouds is valid for 10–1000 GHz. Outside these frequency ranges, the System object uses the nearest valid value. Fig.10 demonstrates the Wideband LOS Channel Model (Power Spectral Density).

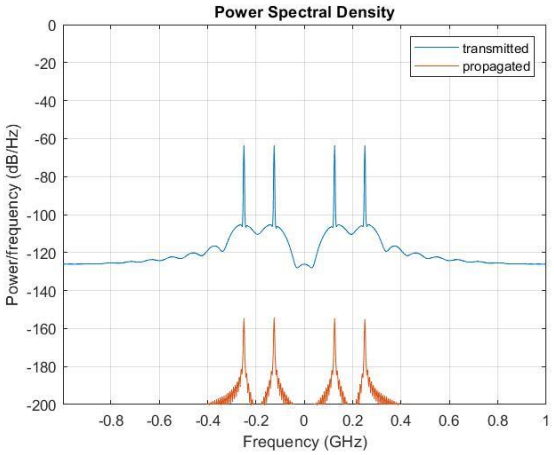



**Fig. 10.** Wideband LOS Channel Model (Power Spectral Density)

The signal power for input excitation for a wide band channel was considered. The noise power is added to the signal power based on the real world applications. The wide band signal power could be observed. The wide band signal with noise power could be acquired. The Wide Band Channel Modelling was designed based on the different condition of noise power in the specific input and channel system for observing the optimization of output received power for the information. Fig.11 illustrates the Wide Band Channel Model with Signal Processing.

Latency analysis in high-speed telecommunication systems is crucial for understanding the delay introduced by various components in the wide band channel network. Fig.12 demonstrates the Latency Analysis in Wide Band Channel Model. The latency in this analysis is unique and includes only transmission time and a fixed processing delay. In a real-world scenario, latency can be affected by many factors, including propagation delay, queuing delay, and more complex processing delays.

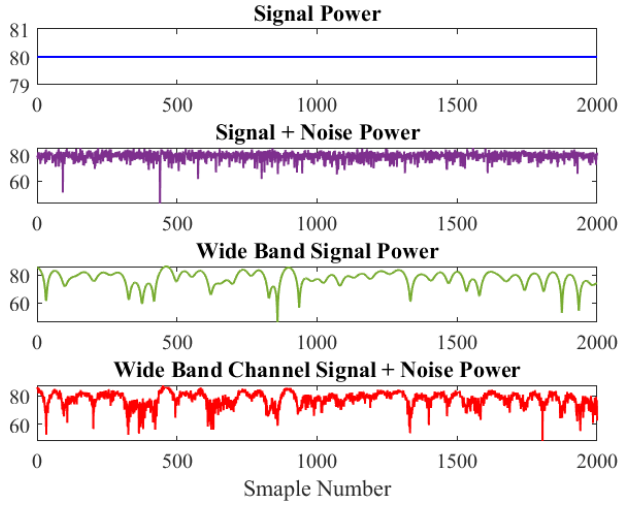



**Fig. 11.** Wide Band Channel Model with Signal Processing

The abovementioned BER calculation provides a measure of the system's performance under the given SNR. The further analyses could be extended for the confirmation of the system design with performance accuracy.

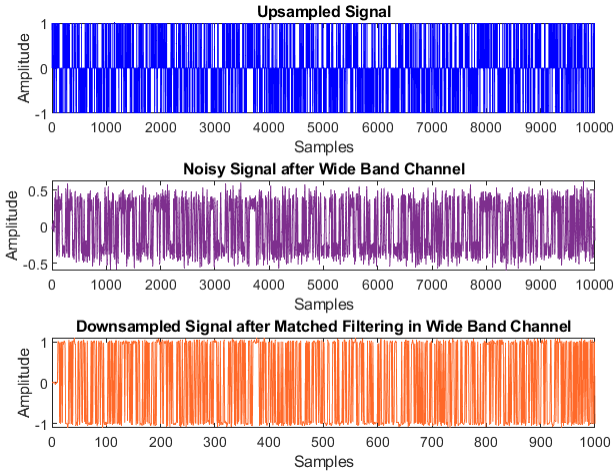



**Fig. 12.** Latency Analysis in Wide Band Channel Model

*D. Statistics Table*

The statistics table for the performance accuracy gives the confirmation of the research outputs of this study by comparing with the recent works. Table I is the performance table of the study. According to the performance comparison, the current study is the best performance for the applications for high speed telecommunication in real world system design.

TABLE. I PERFORMANCE TABLE

| Reference | BER | Capacity | Latency (Transmission Time + Processing Delay) |
|---|---|---|---|
| [5] | 0.985 | 2 Bits/Hz | 1 ms |
| [6] | 0.857 | 5 Bits/Hz | 10 ms |
| [7] | 0.825 | 10 Bits/Hz | 100 ms |
| This Work | 0.519 | 25 Bits/Hz | 2 µs |

## VI. CONCLUSION

Modelling approaches with potential applicability for characterizing propagation for the envisioned applications and current modeling efforts would be evaluated. The unique characteristics of the propagation channel for each of the envisioned applications would be presented and analyzed. Finally, an insight was given to the issues and challenges faced for channel modelling in the 5G system, and potential solutions and research opportunities that must be explored to tackle these challenges would be discussed. The propagation model for free space and line of sight condition could be affected to analyze the concepts of reflecting surface design between transmitted and receiving antennas. Modeling approaches with potential applicability at high speed data rate for characterizing propagation for the envisioned applications and current modeling efforts are evaluated. The unique characteristics of the propagation channel for each of the envisioned applications are presented and analyzed. The hardware constraint and environmental facts are future consideration for the performance specifications and the robustness of the system design is also acceptable for the real world applications.

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