



Doppler Frequency Effect on Network Throughput Using Transmit Diversity

Silas Tyokighir^{a*}, Joseph Mom^b, Noumsi Brice^c

^{a,b,c}*Department of Electrical and Electronics Engineering, Federal University of Agriculture P.M.B. 2373
Makurdi Benue State, Nigeria.*

^a*Email: sootyokighir@gmail.com*

^b*Email: joe.mom@uam.edu.ng*

^c*Email: noumdabri@gmail.com*

Abstract

In this paper, the effect of Doppler shifts on the downlink channel of the Long Term Evolution network is investigated at different frequencies using a new simulation setup. To this aim, an integrated simulation setup has been developed, which includes a cellular environment with a Bernoulli signal generator, a propagation channel with Rayleigh flat fading using four transmit antennas, and two receive antennas. Among the simulation results, the bit error rate of the transmit diversity scheme is analyzed. It is shown that an increase in antenna transmit power provides higher throughput although yields to a higher number of errors.

Keywords: Doppler shift; Long Term Evolution; Rayleigh flat fading.

1. Introduction

The Doppler Effect is the change in frequency of a wave as the source and observer move toward or away from each other causing carrier frequency offset [1] leading to network error hence decreasing overall throughput. Several standards have been set for use in simulating Long Term Evolution (LTE) networks by the 3rd Generation Partnership Project (3GPP) which include three delay profiles for modelling multipath fading.

* Corresponding author.

They include the Extended Pedestrian (EPA), the Extended Vehicular (EVA) and Extended Typical Urban (ETU) delay profile with maximum Doppler frequency as 5, 70, and 300Hz respectively. It is known that as the Doppler frequency increases, the number of errors also increase due to an increase in speed of the signal [2] resulting to a higher number of errors. Orthogonal Frequency Division Multiplexing (OFDM) works by transmitting signals on sub-carriers which are orthogonal to each other. This makes the scheme resilient to carrier frequency offset hence mitigating the effects of both inter-symbol and inter-carrier interference. Another notable scheme used in combating the Doppler Effect is antenna diversity which is a method of achieving diversity gain through the use of multiple antennas either at the transmitter [3] or at the receiver. However, installing multiple antennas at the receiver is cumbersome and uneconomical when compared to the transmit diversity technique which involves installing multiple antennas at the transmitter providing diversity gain for all User Equipment (UE) operating within the base station. The use of computer simulation is paramount due to the fact that an accurate representation of blocks necessary to setup a real life network can be implemented and tested over varying conditions. MATLAB Simulink constitutes the communications system toolbox which can be used in simulating the LTE network based on recent LTE releases. Recent studies have shown that lower modulation schemes such as Quadrature Phase Shift Keying (QPSK) are more robust in the presence of noise when compared to 16 and 64-QAM techniques due to lower number of symbols. Furthermore, previous studies have shown that the 64-QAM modulation schemes produces higher number of errors during network transmissions when compared to QPSK, this is because of the higher number of symbols although had the advantage of higher throughput.

2. Materials and methods

The methodology used involves the studying of the basic characteristics and components of an LTE network and representing them by suitable configured LTE subsystems with the respective attributes using Simulink blocks. The models will be considered for the case of a single source of random binary traffic.

2.1 Simulation model

The model of the LTE downlink channel can be deduced from Figure 1; it consists of the traffic source module, a modulator block, propagation channel, and demodulator block as well as an error rate calculator.



Figure 1: An Integrated Model showing setup of the LTE Network

The source module generates signals based on a discrete-time stochastic process that takes only two values, canonically 0 and 1.

All calculations regarding rate matching, code block concatenation are performed using these set of numbers. Each time a simulation is ran, a different set of numbers are generated but according to a particular sequence. The modulator modulates signals according to either a Quadrature Phase Shift Keying (QPSK) or Quadrature

Amplitude Modulation method. The QPSK block produces 2 bits per symbol and carries less data as compared to the 16QAM and 64QAM. It is also more robust in the presence of noise. The Rayleigh fading channel is where the maximum Doppler frequency, Doppler spectrum and roll off factor are specified. It is known that the higher the Doppler frequency the higher the number of errors.

The noise channel is part of the propagation channel and is usually modeled with the Additive White Gaussian Noise (AWGN) block AWGN adds white Gaussian noise to a vector signal. The scalar signal to noise ratio (SNR) specifies the signal-to-noise ratio per sample, in decibels (dB). If the vector signal is complex, AWGN adds complex noise.

While the error rate calculator computes the bit error rate of the signal. It does this by first transmitting the original signal through the transmission link, it then transmits another delayed version of the same signal after which it compares them at the end of the simulation to determine number of errors.

2.2 Integrated simulation model

Figure 2 depicts the integrated simulation model which comprises the Orthogonal Space Time Block Coding (OSTBC) which functions to encode input signals based on Space Time Block Coding (STBC). Output from the OSTBC encoder is now fed into the transmit diversity 4 by 2 sub-system shown in Figure 3. The advantage of this setup is to increase transmit power and as a result, combat the Doppler Effect and increase network throughput. Maximum Doppler frequency is set at 5Hz across all multi path Rayleigh fading channels. The OSTBC combiner receives the signals along with the channel estimate after noise is added. The output is now demodulated and fed into the error rate calculator where error rates are been calculated.

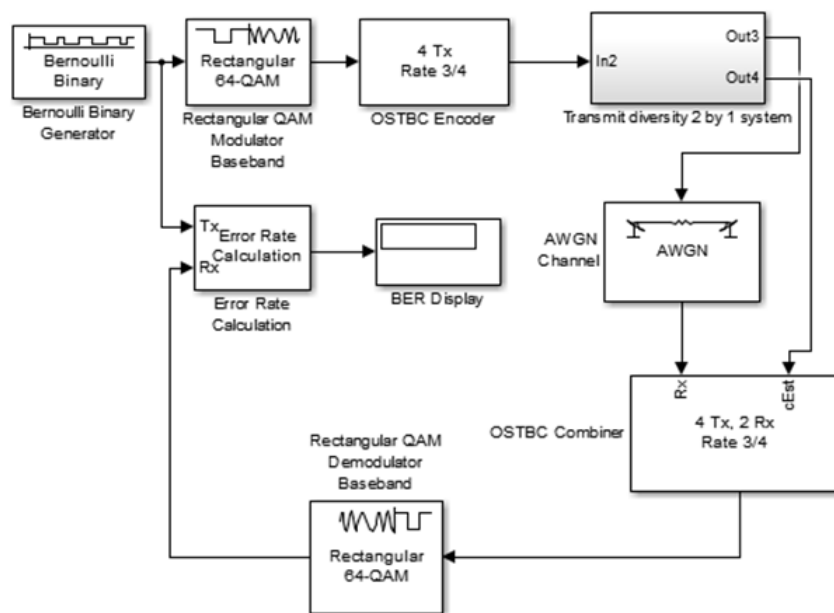


Figure 2: Integrated Simulation Model for Error rate estimation

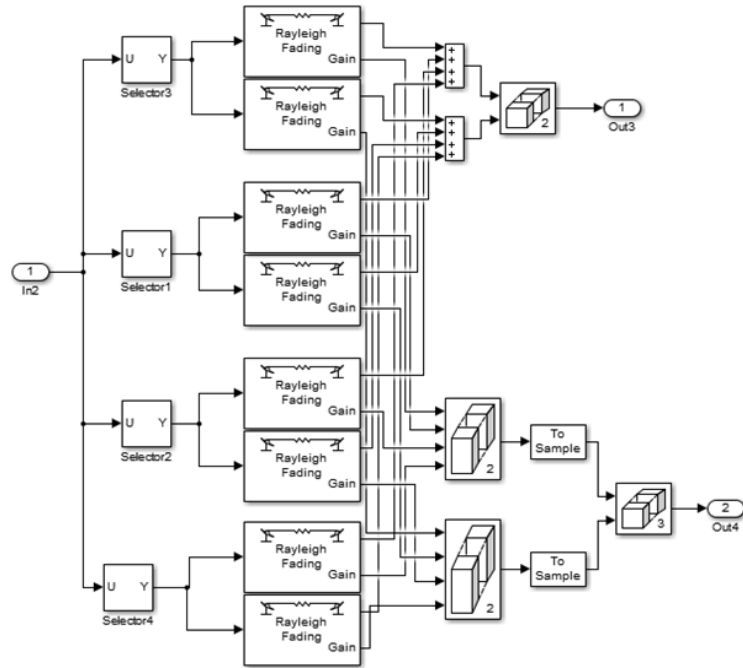


Figure 3: Transmit diversity 4 by 2 Sub-system

3. Results

The results show that as the Doppler frequency increases the number of errors also increase due interference by carriers causing a drop in network throughput.

Table 1: Error rate using the Extended Pedestrian A delay profile

Extended Pedestrian A (5Hz Doppler)	Bit error rate	Number of errors
	0.8818	8.818e+05

From Table 1 it a bit error rate of 0.8818 was realized for a simulation time of 100 seconds. This value would increase with an increase in the simulation time.

Table 2: Error rate using the Extended Vehicular A delay profile

Extended Pedestrian A (70Hz Doppler)	Bit error rate	Number of errors
	0.9018	9.018e+05

The Extended Vehicular A delay profile modes the speed of the user equipment (UE) similar to that of moving vehicles which justifies the use of a higher frequency of 70Hz. From Table 2 bit error rate of 0.9018 was realized for the same simulation time of 100 seconds. A 0.02 error rate disadvantage was realized as the Doppler frequency increased due to a higher number of collision between sub carriers.

Table 3: Error rate using the Extended Typical Urban delay profile

Extended Typical Urban (300Hz Doppler)	Bit error rate	Number of errors
	0.9311	9.311e+05

From Table 3, due to a rapid increase in the Doppler frequency to 300Hz bit error rate of 0.9311 was realized due to the fact that higher speeds causes the mobile equipment to rapidly switch from base stations. This, alongside Doppler shifts affected sub-carriers causing an even higher error rate.

4. Discussion

Taking a close look at error rates from Tables 1, 2 and 3, it will be seen that for the same modulation technique, the throughput achieved by the Extended Pedestrian fading profile is the best. This is because of the maximum Doppler frequency set at 5Hz. By this, sub-carrier interference is reduced causing the number of collisions to also decrease yielding lower bit error rates. With lower bit error rates and Orthogonal Frequency Division Multiplexing (OFDM) both inter-carrier and inter-symbol interference can be kept in control. Previous studies also arrived at conclusions that as the speed of the mobile equipment increases, the Doppler frequency also increases leading to high bit error rates. Furthermore, a common conclusion can be drawn that the QPSK modulation is more robust in the presence of noise. Simulations show that even if the SNR keeps increasing, the throughput will keep on increasing but will be limited within its threshold. On the other hand, the 64-QAM modulation technique would not be capable of surviving for longer periods due to the fact that it doesn't have the capability to withstand higher noise levels. Generally signals with high Additive White Gaussian Noise (AWGN) yields synchronizations problems and gradually dies away. It cannot keep on displaying its stability even if the SNR keeps increasing. In some cases, the signal may even die before reaching its threshold.

5. Conclusion

This work implemented the block-oriented simulation model that can be used for estimating the Doppler frequency effect on network throughput using the Extended Pedestrian, Extended Vehicular and Extended Typical Urban delay profiles. It can be concluded that as the Doppler frequency increases, the number of errors also increase causing a decrease in network throughput. Further extension beyond this point would be to implement the simulation model to support more than one traffic source as well as include the use of the Binary Phase Shift Keying (BPSK) modulation scheme during simulation. Simulations should also be carried out using the RIVERBED modeler communications system software to obtain more accurate results.

6. Recommendations

The 3rd Generation Partnership Project (3GPP) should specify and allocate higher frequencies in the modeling of delay profiles corresponding to very high speed mobile equipment.

Acknowledgements

The Authors would like to thank God almighty for strength and grace to carry out this research. The door to Prof. Igwue's office was always open whenever we had any questions concerning the study.

References

- [1]. S.M. Alamouti. "A Simple Transmit Diversity Technique for Wireless Communications." IEEE Journal on Select Areas in Communications, vol. 10, pp. 1451-1458, August. 1998.
- [2]. N.J., Ahmed, R., Islam, V., Dutta, I.K., Gupta, "Performance Analysis on Throughput in 4G Network in Digital Environment with SISO Technique." International Journal of Information Technology and Computer Science, vol. 5, pp. 71-79, July. 2013.
- [3]. W., Yang, "LTE Physical Layer Performance Analysis." National Institute of Standards and Technology, vol. 3, pp. 6-10, June. 2013.