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Channel Modelling for Multipath Propagation in 4G LTE

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Abstract:
Multipath propagation refers to the various copies of the same signal propagating through the channel with different delays and amplitude gain. While the direct or line of sight path is the main wanted signal, a radio receiver will receive different versions of the same signal that have travelled from the transmitter via many different paths. multipath channel modelling is important for signal simulation and error mitigation in urban scenarios even in Global Navigation Satellite System. In this paper, the emphasis is on developing a model of an OFDM transmitter and receiver system and the channel using AWGN noise and to develop a model for simulating multipath propagation channels. These models made are made for three different delay profiles as per 3GPP TS 36.104 standards. The bandpass signal is generated based on the number of frames used for transmission of the signal. The frame, here, refers to the Frame structure type 1 as defined by the 3GPP standards. This type of frame is used for full duplex FDD communication model. The signal can be added with either short cyclic prefix and extended cyclic prefix at the transmitter side. At the receiver, the procedure complementary to the transmitter happens and cyclic prefix is removed. The transmitter and receiver model are used in order to simulate the results. The power spectral density of the signal after passing through the channels with AWGN and Multipath fading are found for Extended Pedestrian A model, Extended vehicular A model and Extended Typical Urban model. This approach is unique as we are simulating the multipath fading channel by using concept of tap delay and shifting the samples and with the concept of interpolation. This method can be utilized in wireless communication systems for characterization of the multipath channels.

Keywords **—**OFDM (Orthogonal frequency Division and Multiplexing), MCS (Modulation and Coding Scheme), Large Scale Path Loss, Small Scale Multipath Fading, LTE frame, Cyclic Prefix, Multipath propagation and Doppler shift.

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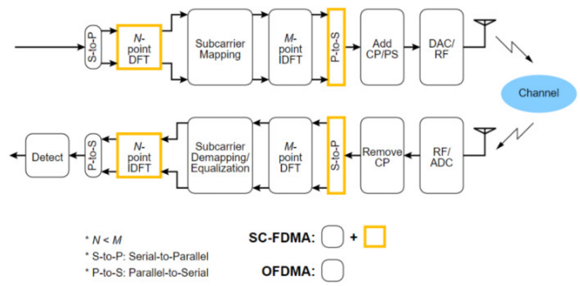
I. INTRODUCTION

Multipath propagation refers to many copies of the same signal travelling through the channel at different times and with variable amplitude gains (attenuation). A radio receiver will receive numerous versions of the same signal that have travelled from the transmitter via many different paths. Although the direct or line of sight path is the main intended signal, all of the signals whether line of sight or non-line of sight are received at the receiver. Multipath fading can occur in any situation where multipath propagation is present and the pathways vary for different reasons. As the path lengths alter, this will affect not just their relative strengths but also their phases. The radio signal may also be distorted as a result of multipath fading. When planning or developing a radio communications system, multipath fading is a feature that must be considered. The signal will reach the receiver in any terrestrial radio communications system not only by the direct path, but also by reflections from objects such as buildings, hills, ground, water, and other things that are near to the primary path. The total signal received by the radio receiver is a sum of the various signals received. There will be variations in relative path lengths from time to time. Moving the radio transmitter or receiver, or any of the things that create a reflective surface, could cause this. As a result of the diverse ways in which the signals arrive to the receiver, the phases of the signals arriving at the receiver will change, and the signal intensity will vary. A baseband signal is generated for implementation of transmission through practical channel conditions. Multipath environment is simulated and the signal is passed through it based on SC-FDMA (Single Carrier-Frequency Division Multiple Access). Single-carrier FDMA (SC-FDMA) transmission processing is quite similar to OFDMA transmission processing. The transmission of bits is mapped to a complicated constellation of symbols for each user (BPSK, QPSK or M-Quadrature amplitude modulation). Then various Fourier coefficients are assigned to distinct transmitters (users). This task is completed in the mapping and de-mapping sections. For each user signal to be received, the receiver side includes one de-mapping block, one Inverse Discrete Fourier Transform (IDFT) block, and one detection block. Guard intervals (called cyclic prefixes) with cyclic repetition are placed between blocks of symbols, similar to how they are in OFDM, to effectively minimize inter-symbol interference caused by temporal spreading (produced by multipath propagation) among the blocks. Owing to its inherent service structure, a distinguished gain of SCFDMA over OFDM and OFDMA is that its transmitted signal has a decrease peak-to-average power ratio ensuring fewer clipping distortions. After the modelling of the transceiver system, the channel is modelled by adding AWGN noise to the signal and sending it to the receiver block. The signal is then passed through a multipath propagation channel. Channel modelling is done to simulate Large Scale Path Loss and Small-Scale Multipath Fading to provide corresponding power loss in the signal power in terms of path loss and fading respectively [2]. The baseband signal has only been generated to aid in the implementation of practical channel conditions.

Fig. 1: The OFDMA and SC-FDMA Transmitter and receiver model



II. LTE FRAME STRUCTURE

The LTE frame structure used in this paper is Frame structure type 1 as shown in fig.2 is a frame structure for data transmission and maintaining synchronization between transmitter (TX) and receiver (RX). This frame is used for FDD type of communication. Each such frame is of time period 10 ms. Each frame constitutes of 10 sub-frames of 1 ms per sub-frame. Each such sub-frame consists of 2 slots which are of 0.5ms each. Each of these slots has 7 OFDM symbols if normal CP is used and 6 OFDM symbols if extended CP is used. Each slot is made up of Resource Block (RB)s. All the RBs for a sub-frame are present in a resource grid. Each member of a resource grid is called resource element (RE). Each RB is made up of 12 subcarriers and 7/6 OFDM symbols.

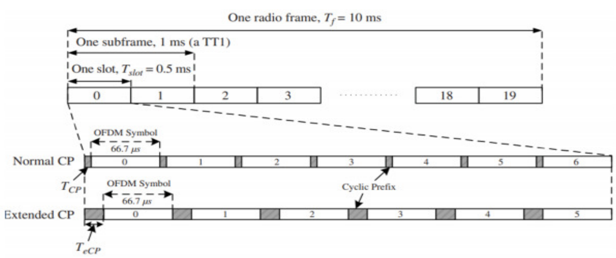


Figure 2: Frame structure type 1

III. MODELLING OF MULTIPATH PROPAGATION CHANNEL

Multipath propagation refers to many copies of the same signal travelling through the channel at different times and with variable amplitude gains (attenuation). A radio receiver will receive numerous versions of the same signal that have travelled from the transmitter via many different paths. The received multipath signal consists of different copies of same signal arriving at different instants in time and with different power. These specifications are taken from 3GPP TS 36.104 for three delay profiles viz.

- Extended Pedestrian A model (EPA)
- Extended vehicular A model (EVA)
- Extended Typical Urban model (ETU)

The Multipath channel tap delays and corresponding relative attenuations have been taken from 3GPP TS 36.141 [6]. This provides the data mentioned in Table 1 for the three EPA (Extended Pedestrian Model A), EVA (Extended Vehicular Model A) and ETU (Extended Terrestrial Urban Model). The baseband signal was generated and passed through this channel with SC- FDMA implementation. The input signal was scaled to the standard deviation value of unity. The standard deviation values for the output were observed for the three models. The mean of these values for over various modulations and SNRs (ranging from 1-30) for addition of AWGN (Additive White Gaussian Noise),wastaken.Thisvaluewasusedasthestandard deviation for modelling small scale multipath fading with Rayleigh distribution. The PSDs (Power spectral Density) of the signal with and without multipath fadinghasbeenshowninFigures3, 4and5for allthe 3 models. Two gaussian distributions with the above obtained standard deviation value were used to obtain Rayleigh fading coefficients. To account for the variable channel conditions and movement of users a Doppler filter was applied on these two gaussian distributionsbasedontheYoung'sModel.Then,these distributions were used to form a Rayleigh distribution. IDFT operation was performed on the magnitude of the Rayleigh distributed values [1]. Thus,foreachuser,foreveryTTI(TransmissionTime Interval), a multipath fading value was obtained. A plot of fading values of a user moving at a particular speed vs TTIs is shown in Figure6.

The baseband signal was generated and passed through this channel with SC-FDMA implementation. The input signal was scaled to the standard deviation value of unity. The standard deviation values for the output were observed for the three models. The mean of these values for over

Excess tap delay [ns]	Relative Power [dB]
0	0.0
30	-1.0
70	-2.0
90	-3.0
110	-8.0
190	-17.2
410	-20.8

Table 1(a): Extended Pedestrian A model (EPA)

Excess tap delay [ns]	Relative Power [dB]
0	0.0
30	-1.5
150	-1.4
310	-3.6
370	-0.6
710	-9.1
1090	-7.0
1730	-12.0
2510	-16.9

Table 1(b): Extended Vehicular A model (EVA)

Excess tap delay [ns]	Relative Power [dB]
0	-1.0
50	-1.0
120	-1.0
200	0.0
230	0.0
500	-0.0
1600	-3.0
2300	-6.0
5000	-7.9

Table 1(c): Extended Typical Urban Model (ETU)

Table 1: Excess tap delay and Relative power values for multipath signals as per 3GPP TS 36.141

various modulations and SNRs (ranging from 1-30) for addition of AWGN (Additive White Gaussian Noise), was taken. This value was used as the standard deviation for modelling small scale multipath fading with Rayleigh distribution. The PSDs (Power spectral Density) of the signal with and without multipath fading has been shown in Figures 3, 4 and 5 for all the 3 models.

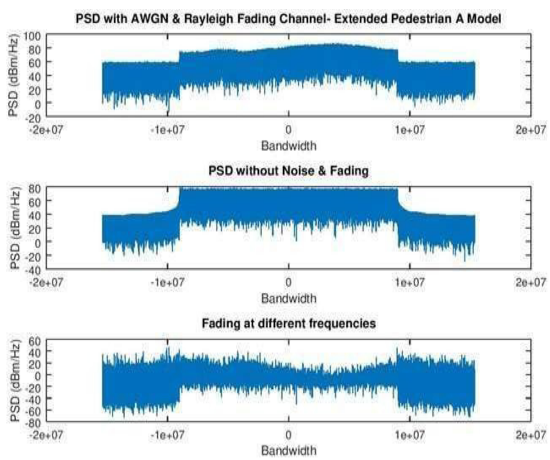


Fig. 3: The power spectral density of Signal-Extended Pedestrian A model

The figure 3 shows the fading characteristics for EPA model developed. As compared to the PSD of the signal without fading, the fading in the signal after passing through the multi-path propagation channel for pedestrian model is more. There is fading uneven at different frequencies. Some frequencies are affected more than others.

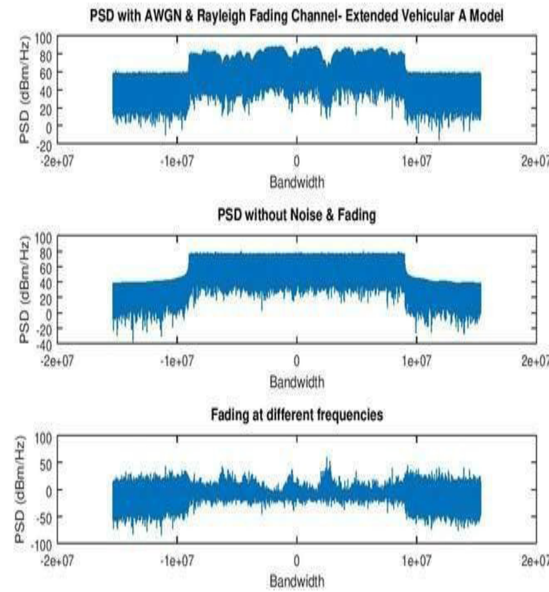


Fig.4: The power spectral density of Signal-Extended Vehicular A model

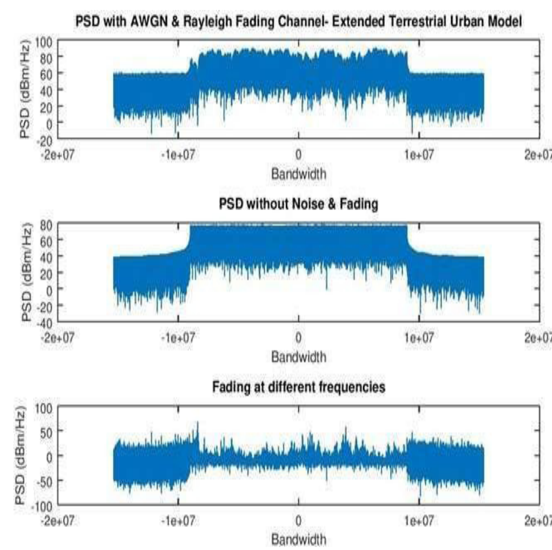


Fig.5: The power spectral density of Signal-Extended Terrestrial Urban mode

The figure 4 shows the fading characteristics for EVA model developed. As compared to the PSD of the signal without fading and EPA model, the fading in the signal after passing through the multi-path propagation channel for vehicular model is higher. This is because the movement of the user in EVA model is through vehicles at higher speeds. The high-speed travel affects the signal quality in the channel because of unpredictably varying channel characteristics. The fading is non-uniform at different frequencies. Some frequencies are affected more than others. The magnitude of fading at different frequencies is show in the third plot in the fig.4.

The figure 5 shows the fading characteristics for developed ETU model. As compared to the PSD of the signal without fading and EPA model and EVA, the fading in the signal after passing through the multi-path propagation channel for typical urban model is higher. This happens due to the fact that the infrastructure in cities is dense and the amount of reflection and diffraction that happens around the building corners is also high. The loss of signal power is significantly high for this particular reason. There is also scattering of signals that happens and these scattered signals are lost in the channel and never received, resulting in loss of data at certain frequency sub-carriers. The fading is non-uniform at different frequencies. The variation in the PSD of the signal is also higher in this model. Some frequencies are affected more than others. The magnitude of fading at different frequencies is shown in the third plot in the fig.5.

Two gaussian distributions with the above obtained standard deviation value were used to obtain Rayleigh fading coefficients. To account for the variable channel conditions and movement of users a Doppler filter was applied on these two gaussian distributions based on the Young's Model. Then, these distributions were used to form a Rayleigh distribution. IDFT operation was performed on the magnitude of the Rayleigh distributed values [1].

Thus, for each user, for every TTI (Transmission Time Interval), a multipath fading value was obtained. A plot of fading values of a user moving at a particular speed vs TTIs is shown in Figure 6.

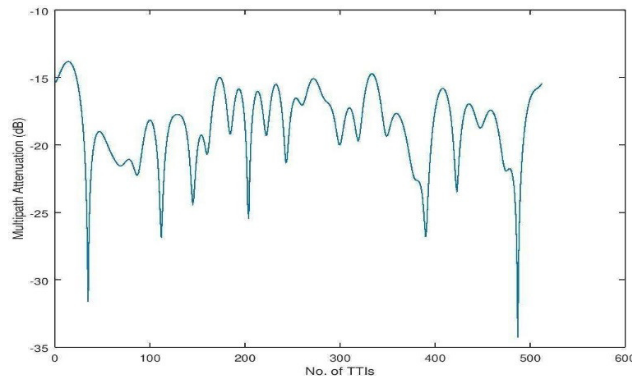


Fig. 6: Multipath attenuation in each TTI TTI

The Hata – Okumura Model was implemented for the simulation of Large-scale path loss, depending upon the distance and height of users from the base station, height of the base station and the center frequency. The value of these factors was randomly chosen from the ranges specified by the model itself for each user.

IV. CONCLUSIONS

It can be inferred that the fading is higher in urban environment (ETU) than an open area type of environment, as in EPA and EVA. Also, the higher the UE speed, the higher is the fading, as evident from comparing EPA and EVA.

The most important aspect for the analysis of signal propagation, either in civilian communication or satellite communication is channel modelling and its analysis. The topic under focus was multi-path propagation fading channel. The model that was developed was able to showcase the fading for three different delay profiles viz. EPA, EVA and ETU. Also, the number of multi-path signals can also be varied in this model, which makes the model more versatile. This approach is unique as we are simulating the multipath propagation fading channel by using concept of the tap delay by shifting the samples. The PSD of the signal shows the effect of the frequency selective fading. This method can be utilized in wireless communication systems such as LTE and GNSS for characterization of the multi-path channels.

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