Mobility Effect on The 3GPP Typical Urban Area channel

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Abstract: - 3GPP Typical Urban Area channel model is used to measure the performance of different systems. This paper showed that the channel imposes a slow fading effect at f_D= 5 Hz and fast fading effect at f_D= 100 Hz. This effect is caused by the user mobility. A further analysis shows that Typical Urban Areas tend to be frequency selective for wide band signals with a coherence bandwidth equals to half of the transmitted bandwidth. The mobility of users decides how fast the fading is affecting the transmitted signals. For low mobility condition (f_D= 5 Hz), the channel shows a significant change every 25 (ms) which is quite slow according to the delay requirements of wide band communication. However, as the mobility increases (f_D= 100 Hz) the channel tends to vary significantly in the order of few milliseconds.

Key-Words: - Time Delay Spread, Coherence Bandwidth, Coherence time and Doppler Spread.

1 Introduction

In order to design efficient wireless systems, designers have to have a good knowledge about the wireless channel which is categorized into two main terms, large scale fading and small scale fading [1]. Large scale fading is caused by two factors, path losses and shadowing, path losses is caused by the distance differences between the transmitter and the receiver. Shadowing is caused by large objects that block the path between the transmitter and receiver. Small scale fading is a phenomenon caused by multipath signals reflected or scattered by the channel obstructions and surfaces. These signals add constructively or destructively in the receiver, implying a distortion which could leads to a complete cancellation of the transmitted signal.

Small scale fading is a very important factor to measure the robustness of the wireless system against multipath signals; hence 3GPP introduced the following three different channel models for system performance measurement, Typical Urban Area, Rural Area and Hilly Terrain Areas. The three channel models are described by theire channel impulse responses which gives details about each path in terms of its power in (dB) and time delay in (μs) [2].

Receivers do not need a full description of the wireless channel rather than needing a parameterized description through important parameters i.e. Coherence Time Doppler Spread Coherence Bandwidth and Delay spread.

The channel presentation in [2] does not provide enough information to realize these parameters, in [3], [4] and [5] a better description for an indoor channel is done through the delay spread parameter. Work at [6] models urban area using ray tracing models, however ray tracing models are based on deterministic conditions which are a rare case in communication systems. Work at [7] describes only the time delay measurements of urban areas, but there is no literature providing a detailed determination of the behavior of the Typical Urban Areas through the mentioned parameters.

In this paper, we present the important parameters that characterize the 3GPP Typical Urban Area in terms of Time and Frequency Coherence.

This paper is organized as follows, Section **(2)** presents an overview about Channel Impulse Response from which it different parameters are derived, Section **(3)** explains in details the Time Delay Spread, Coherence Bandwidth, Coherence time, and Doppler Spread. Section **(4)** presents the 3GPP Channel Model. Section **(5)** describes the simulation model. In section **(6)** simulation results are presented and the paper is concluded in section **(7)**.

2 Time Varying Impulse Response

If a single Impulse is transmitted through a wireless Channel, Assuming the environment contains a number of scatterers and reflectors with different attenuation factors, the impulse will be received in the form of the following equation:

$$c(\tau;t) = \sum_{n=0}^{N(t)} \alpha_n(t).e^{-j\phi_n(t)}.\delta(\tau - \tau_n(t)) \qquad (1)$$

Where:

N: maximum number of multipath signals

α_n : Received power of the multipath signal *n*.

τ_n : Time delay of the multipath signal *n*.

ϕ_n : Phase of multipath signal *n*.

Very important parameters can be derived from the channel impulse response which characterizes the behavior of the channel for wideband and narrow band transmitted signals.

3 Time Delay Spread, Coherence Bandwidth, Coherence time and Doppler Spread

According to the impulse response of the channel an important parameter can be derived from the estimated multipath gains and delays. This parameter is called **Delay spread** (T_m), which has three main definitions:

1. If the receiver is synchronized to the first multipath component Then the delay spread is defined as the maximum delay difference between the received multipath signals,

$$T_m = \max_n(\tau_n - \tau_0) \qquad (2.1)$$

2. If the receiver is synchronized to the mean delay, then the delay spread is defined as difference between the maximum delay and the mean delay ($\bar{\tau}$)

$$T_m = \max_n |\tau_n - \bar{\tau}| \qquad (2.2)$$

3. Due to the low gains of some multipath signals which are below the noise floor, RMS delay spread is used to characterize the spreading behavior of the channel, which estimates the delay spread according to the contribution of each multipath signal to the fading process.

$$T_{rms} = \sqrt{\overline{\tau^2} - \overline{\tau}^2},$$
$$where \rightarrow \overline{\tau^m} = (\sum_{n=0}^{N} \tau_n{}^m.\alpha_n{}^2)/(\sum_{n=0}^{N} \alpha_n{}^2) \qquad (2.3)$$

In this paper, the RMS delay spread is to be considered since it is the most reasonable definition to characterize the spreading behavior of the channel. The characterization of the time varying multipath channel in the frequency domain by taking the Fourier transform of the channel Impulse Response *c(τ;t)* with respect to (τ) as follows :

$$C(f;t) = \int c(\tau;t).e^{-j.2\pi f\tau} d\tau \qquad (2.4)$$

Since the autocorrelation function $A_C(\Delta f;\Delta t)$ of *C(f;t)* in the frequency domain depends only on the frequency Δf [6], the **coherence bandwidth** B_c can be defined as the range of frequencies where $A_C(\Delta f;0) \approx 0$ for all $\Delta f > B_c$. The coherence Bandwidth is related to the delay spread through the autocorrelation of the channel impulse response in the time domain $A_c(\tau)$. If $A_c(\tau) \approx 0$ for $\tau > T_{rms}$, then $A_C(\Delta f) \approx 0$ for $\Delta f > 1/T_{rms}$ [6].

Delay spread and Coherence Bandwidth characterizes the fading process into flat fading or frequency selective fading. In linear modulation, the Bandwidth *B* of the signal is inversely proportional to the symbol period T_s, then the fading process said to be flat if $B \ll B_c$ or $T_s \gg T_{rms}$. And the process is said to be frequency selective if $B \gg B_c$ or $T_s \ll T_{rms}$.

The time variation of the channel which arises from the movement of the transmitter or receiver causes a Doppler shift in the received signal. The Doppler effect can be captured by the Fourier transform of $A_C(\Delta f;\Delta t)$ with respect to Δt. The **Doppler spread** B_d is defined by the maximum Δt which $A_C(\Delta f = 0;\Delta t) > 0$. [7] refers to B_d as $2.f_D$ where f_D is the maximum Doppler frequency. Channel **coherence time** T_c is the period of time overwhich $A_C(\Delta t) = A_C(\Delta f = 0;\Delta t) \neq 0$.

Coherence Time and Delay spread are related through the relationship between $A_C(\Delta t)$ and its Fourier Transform where $T_c \approx 1/B_d$. Work at [6] refers to T_c as $1/(4.B_d)$ where the changes of the phase of received signal need to be analyzed in the order of half wavelength.

4 3GPP Typical Urban Area

The table below describes 20 multipath signals with its relative delays and powers. This channel description does not give an insight in the behavior of the channel and needs to be analyzed to provide designers with information that can be used to evaluate future wireless system performance in typical Urban Areas:

Tap number	Relative time (µs)	average relative power (dB)	doppler spectrum
1	0	-5.7	Class
2	0.217	-7.6	Class
3	0.512	-10.1	Class
4	0.514	-10.2	Class
5	0.517	-10.2	Class
6	0.674	-11.5	Class
7	0.882	-13.4	Class
8	1.230	-16.3	Class
9	1.287	-16.9	Class
10	1.311	-17.1	Class
11	1.349	-17.4	Class
12	1.533	-19.0	Class
13	1.535	-19.0	Class
14	1.622	-19.8	Class
15	1.818	-21.5	Class
16	1.836	-21.6	Class
17	1.884	-22.1	Class
18	1.943	-22.6	Class
19	2.048	-23.5	Class
20	2.140	-24.3	Class

Table (1): 3GPP TypicalUrban Area Channel Model [2]

5 Simulation Description

- A 5MHz pulse is sent every 0.1024 (ms) through the 3GPP Typical Urban Area which is simulated By MATLAB/SIMULINK. Then, the pulse is contaminated by AWGN (Additive White Gaussian Noise).
- The contaminated complex multipath signals are normalized and squared to obtain their relative power.
- A FFT (Fast Fourier Transform) is carried out on the multipath signals to estimate the frequency response of the transmitted pulse.
- The channel response in time domain is analyzed through a 3 dimensional plot.
- The Phase variation is described through a scatter plot and a 2D plot for a 100(ms) snapshot.
- The mobility of the transmitter or receiver is modeled through the Doppler shift. In this paper, a Doppler shift (f_D = 5 Hz and 100 Hz) is taken into account.

The Simulation Model is described in Figure (1):

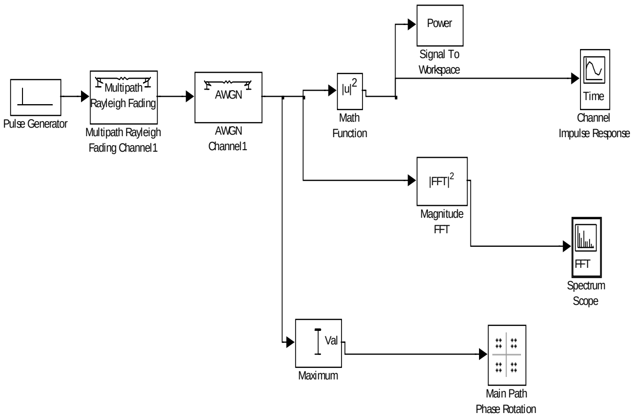

Figure (1): Simulation Model

6 Simulation Results

- Coherence Time And Doppler Spread for The 3GPP Typical Urban Area at (f_D=5 and 100 Hz):

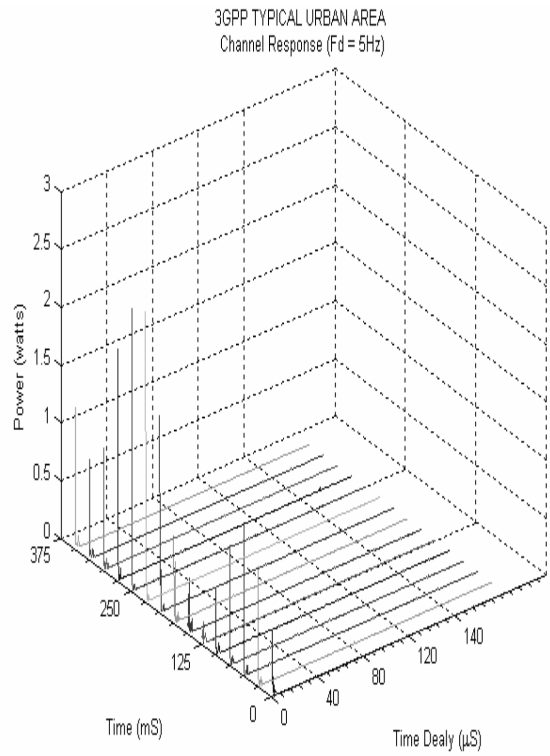

Figure (2): 3GPP TYPICAL URBAN AREA Channel Impulse Response with Doppler shift (f_D = 5Hz).

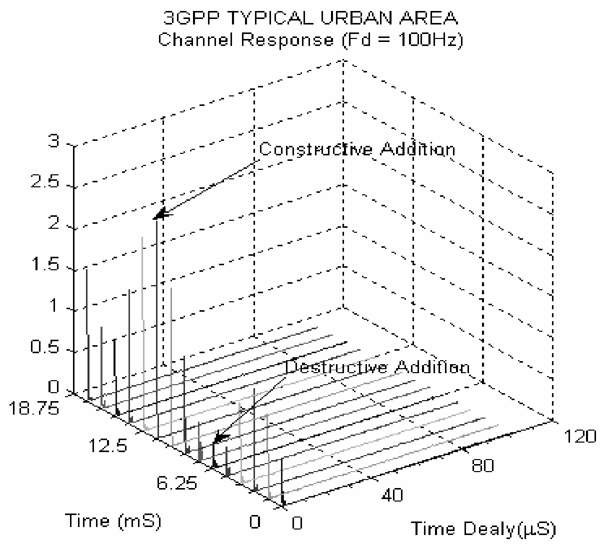

Figure (3): 3GPP TYPICAL URBAN AREA Channel Impulse Response with Doppler shift (f_D = 100 Hz).

The 3D plot gives a better insight in understanding the channel coherence time and how fast the channel is varied due to the Doppler shift. According to the Coherence Time and Doppler spread relationship $T_c \approx 1/(4.B_d)$, a snapshot is taken every 25 (ms) in Figure (2), Which shows a significant change every T_c. After 125 (ms) of simulation a null in the received signal caused by a destructive addition occurred, according to delay requirements of future applications which is in the order of few milliseconds. The 3GPP Typical Urban Area at (f_D = 5Hz) is considered a slow fading channel with T_c =25(ms), and a Doppler spread B_d = 10 Hz.

In Figure (3) a snapshot is taken every T_c = 1.25 (ms) which shows a significant change in the channel at each snapshot. This fast variation compared to Figure (2), is due to the increasing, in the receiver or transmitter, velocity measured by B_d = 200 Hz. A null occurred after 6.25 (ms) concludes that the 3GPP Typical Urban Area at (f_D = 100 Hz) acts as a fast fading channel compared to the condition where (f_D = 5 Hz).

The fast variation of the channel can be viewed also by how fast the phase of the received signal is varied. In order to see that a snapshot of 100(ms) duration is been taken for both (f_D =5 and 100 Hz) cases as shown in Figure 4 and Figure 5 :

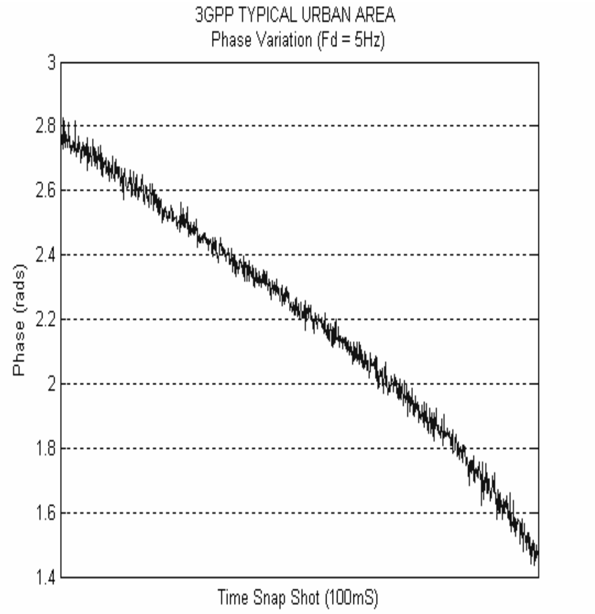

Figure (4): Typical Urban Area Phase variation at (f_D =5 Hz).

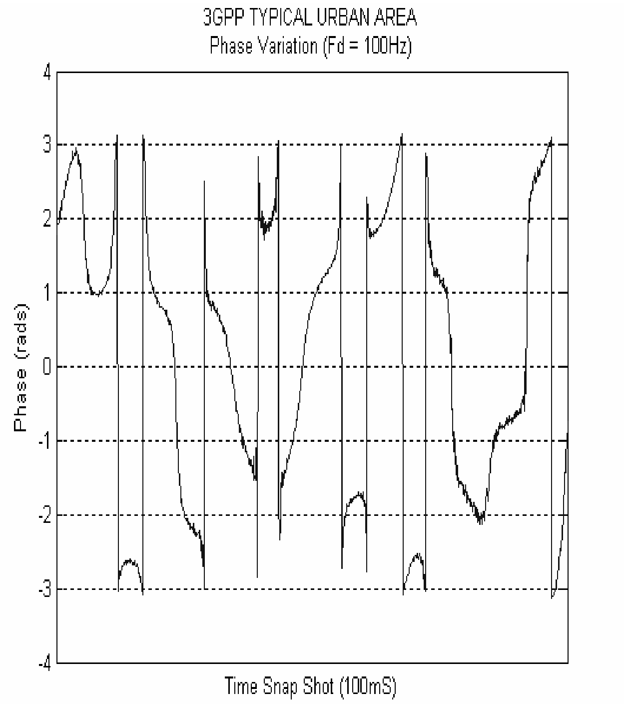

Figure (5): Typical Urban Area Phase variation at (f_D =100 Hz).

Comparing Figure (4), and (5) shows that as the mobility of the users increases the phase variation will increase, since Doppler frequency shift is proportional to the rate of phase change.

Delay Spread and Coherence Bandwidth for The 3GPP Typical Urban Area at (f_D =5 and 100 Hz):

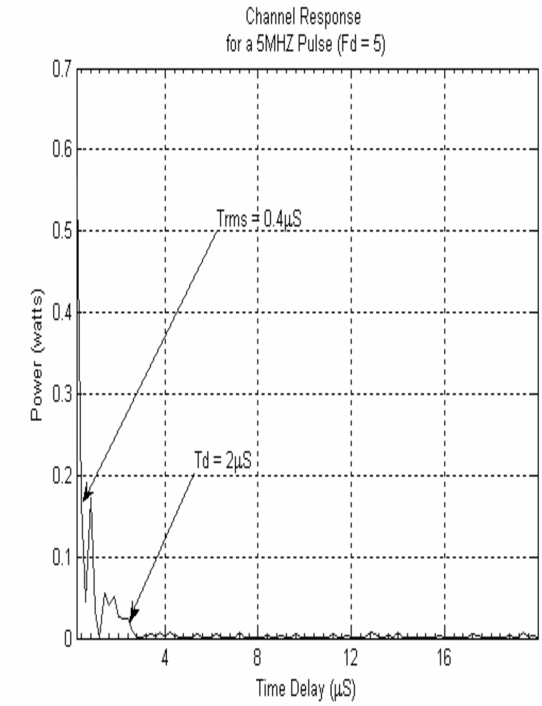

Figure (6): Channel Response at (f_D =5 Hz and 100 Hz).

Referring to equation (2.1) the delay spread T_m = 2µs. However equation (2.3) is the most preferred to define the delay spread in terms of T_{rms} which equals 0.4 µs. From Figure (6) its shown that the spreading behavior of the channel in the time domain does not depend on the users mobility rather than depending on the physical condition of the channels (number of reflectors) and the signals bandwidth. In this paper, a signal bandwidth of 5 MHz is chosen which is the bandwidth used for WCDMA systems. Typical Urban Areas tend to be frequency selective channels where the signal duration tends to be less than T_{rms} of the channel, T_s = 0.2µs << T_{rms} = 0.4 µs, and the signals bandwidth is greater than coherence bandwidth of the channel B = 5 MHz >> B_c = 2.5 MHz.

Table (2) shows the main properties of the 3GPP Typical Urban Area:

	f_D = 5 Hz	f_D = 100 Hz
Coherence Time T_c	25 (ms)	125 (ms)
Doppler Spread B_d	10 Hz	200 Hz
Delay Spread T_{rms}	0.4 µs	0.4 µs
Coherence Bandwidth B_c	2.5 MHz	2.5 MHz
Fast Fading	No	Yes
Slow Fading	Yes	No
Frequency Selective Fading	Yes	Yes

Table (2)

7 Conclusion

3GPP Typical Urban Area channel model is used to measure the performance of different systems. This paper shows that the channel imposes a slow fading effect at f_D = 5 Hz and fast fading at f_D = 100 Hz these effects are due to the user mobility. This variation is shown through the channel time domain response and the phase variation through time.

For systems with 5 MHz bandwidth such as WCDMA the channel tends to be frequency selective. This problem can be solved by multiple diversity techniques.

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