FADING ANALYSIS OF THE 3GPP RURAL AREAS

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Abstract:
3GPP Rural Area channel model is used to measure the performance of different wireless systems i.e. UMTS, WLAN and WiMax. This paper showed that the channel impose a slow fading effect at f_D = 5 Hz and fast fading at f_D = 100 Hz these details shows how the user mobility affect the data reception. A further analysis shows that Rural Areas tends to be flat for wide band signals with a coherence bandwidth equals to the half of the transmitted bandwidth. 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 communications, however as the mobility increases (f_D = 100 Hz) the channel tends to vary significantly in order of few milliseconds.

***KEYWORDS**: Fast and slow fading, flat fading.*

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].

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

The channel presentation in [2] does not provide enough information to realize these parameters, in [5], [6] and [7] a better description for an indoor channel is done through the delay spread parameter, [6] presents an extensive field trials in rual areas showing that Rician PDF models the rural areas propagation, For urban mobile-radio environments, [8] proposed a ray-theoretical method, in which the ray-theoretical waves, diffracted and reflected by building walls, were calculated based on a topological building database, to predict the mean field strength. They successfully used this method to predict the mean field strengths in the VHF, UHF. And **1.2-GHz** bands [5]. Extended this method by taking scattering by walls into account, using physical optics and the bistatic radar equation. The delay profiles predicted for the urban-mobile channel, at 450 **MHz,** agreed well with the measurements [3]. Reflections from mountain surfaces were also evaluated by the bistatic radar equation, taking the absorption by the mountain into account.

The randomness of the received signal due to multipath problem made the problem of recovering the transmitted information very hard; in order to resolve this problem a number of techniques been proposed i.e. equalization, OFDM modulation, spectrum spreading and different channel coding. However in order for these techniques to overcome the multipath effect they need to have a parameterized description through important parameters i.e. Coherence Time, Doppler Spread, Coherence Bandwidth and Delay spread [3], [4].

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

This paper is organized as follows, In section **(2)** presents an overview about Channel Impulse Response which from it different parameters are derived, In section **(2.1)** explains in details Time Delay Spread, Coherence Bandwidth, Coherence time, and Doppler Spread, In section **(2.2)** describes the simulation model, In section **(2.3)** the 3GPP Channel Model is presented, section **(2.4)** presents simulation results and finally In section **(3)** the paper is concluded.

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.

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

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.

Coherence Bandwidth:

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)

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

Since the autocorrelation function $A_C(\Delta f;\Delta t)$ of *C(f;t)* in the frequency domain depends only on the frequency Δf [8]. 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

$$\Delta f > 1/T_{rms} \text{ [3].}$$

Delay spread and Coherence Bandwidth characterize 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 $B << B_c$ or $T_s >> T_{rms}$. And the process said to be frequency selective if $B >> B_c$ or $T_s << T_{rms}$.

The time variations of the channel which arise from the movement of the transmitter or receiver cause 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 $A_C(\Delta f = 0;\Delta t) > 0$. [4] Refers to B_d as $2.f_D$ were f_D is the maximum Doppler frequency. Channel **coherence time** T_c is the period of time over which $A_C(\Delta t) = A_C(\Delta f = 0;\Delta t) \neq 0$. Coherence Time and Delay spread are related through the relationship between $A_C(\Delta t)$ and its Fourier Transform where $T_c \approx 1/B_d$. [3]. Refers to T_c as $1/4.B_d$ where the changes of the phase of received signal need to be analyzed in order of half wavelength.

2.2. 3GPP Typical Urban Area:

Table (1) below describes 10 multipath signals with there relative delays and powers, this channel description does not give an insight to the channel behavior and needs to be analyzed to provide designers with information that can be used to evaluate data quality through Rural Areas.

Tap number	Relative time (μs)	average relative power (dB)
1	0	-5.2
2	0.042	-6.4
3	0.101	-8.4
4	0.129	-9.3
5	0.149	-10.0
6	0.245	-13.1
7	0.312	-15.3
8	0.410	-18.5
9	0.469	-20.4
10	0.528	-22.4

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

2.3. Simulation Description:

- A 5MHz pulse is sent every 0.1024 (ms) through the 3GPP Rural Area which is simulated By MATLAB/SIMULINK, then the pulse is contaminated by AWGN (Additive White Gaussian Noise).
- The Power of the transmitted signal is normalized to equal 0 dB (1 watt).

- 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):

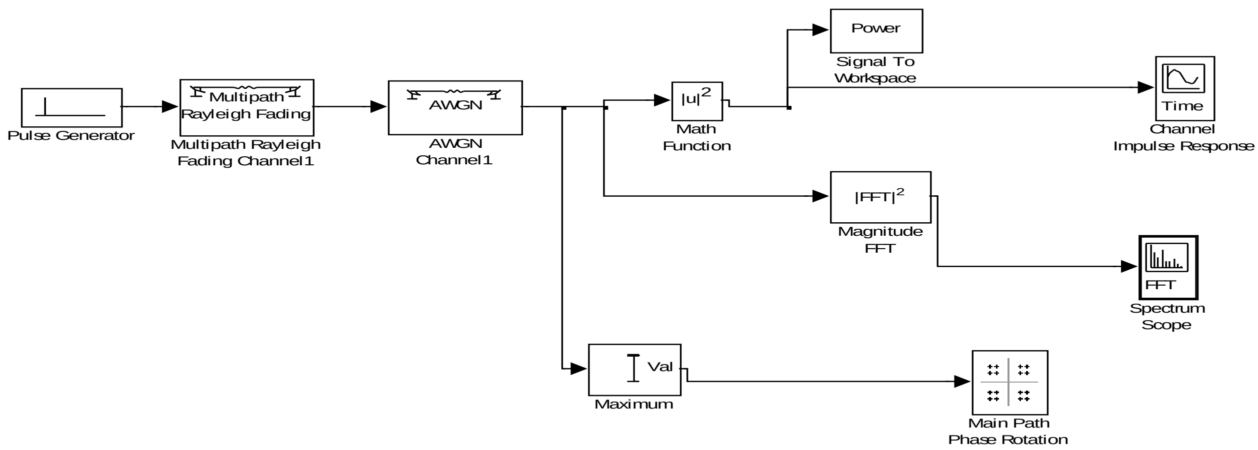

Figure (1): Simulation Model

2.4. Simulation Results:

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

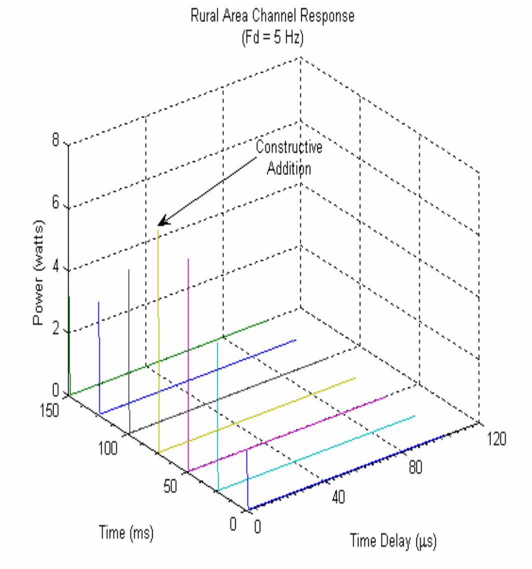

Figure (2): 3GPP Rural Area Channel Impulse Response with Doppler shift (f_D = 5Hz)

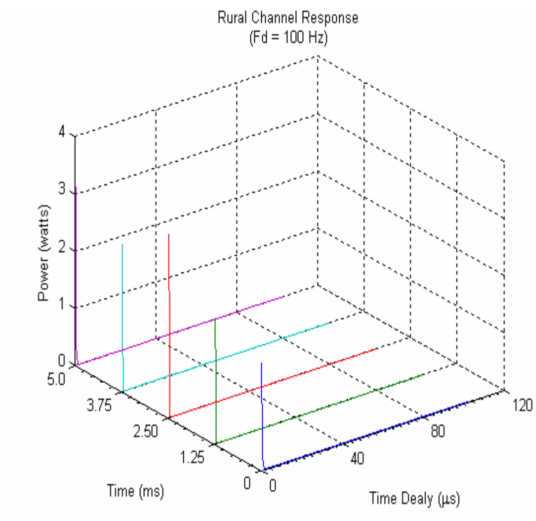

Figure (3): 3GPP Rural Area Channel Impulse Response with Doppler shift (f_D = 100 Hz)

The 3D plot give a better insight to understand the channel coherence time and how fast the channel varies due to the Doppler shift, a significant change occurs each $T_c \approx 1/(4.B_d) = 25$ (ms), Figure (2) shows this change, where X , Y abscissas represents the time delay and time domain and the Z abscissa represents the power in (watts), after 100 (ms) of simulation a constructive addition happened showing that the multipath signals added together producing a high received power = (6 watts) compared to the transmitted signal power which is (1watt), this constructive addition could be damaging rather than being beneficial, because amplifiers at the receiver side will be saturated causing large amount of distortion to the received signal. From this we can see the advantage of taking $T_c \approx 1/(4.B_d)$; since it can detect significant changes where these observations could be missed if we used $T_c \approx 1/(2.B_d)$.

Coherence Time is used to determine if the channel is either slow or fast based on the delay requirements of the system being under analysis, according to delay requirements of future applications which is in the order of few milliseconds the 3GPP Rural 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 increase in the receiver or transmitter velocity measured by B_d = 200 Hz. A duplication of the signal power occurred after 5 (ms) concluding that the 3GPP Rural 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 varies, in order to see that; a snapshot of 100(ms) duration is been taken for both (f_D=5 and 100 Hz) cases.

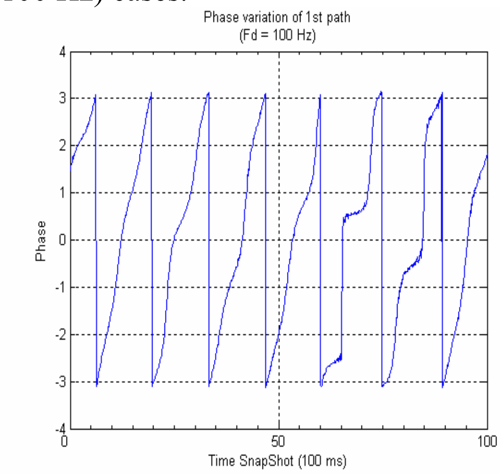

Figure (4): Rural Area
Phase variation at (f_D=100 Hz)

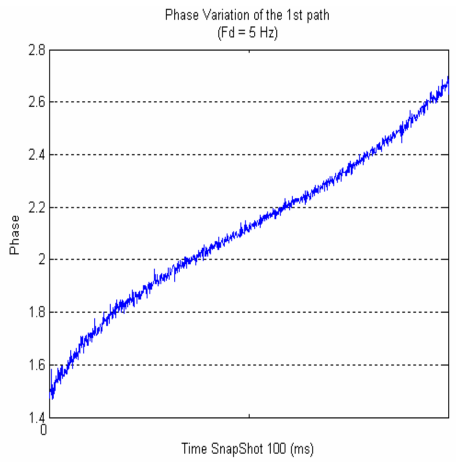

Figure (4): Rural Area
Phase variation at (f_D=5 Hz)

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 Rural Area at (f_D=5 and 100 Hz):

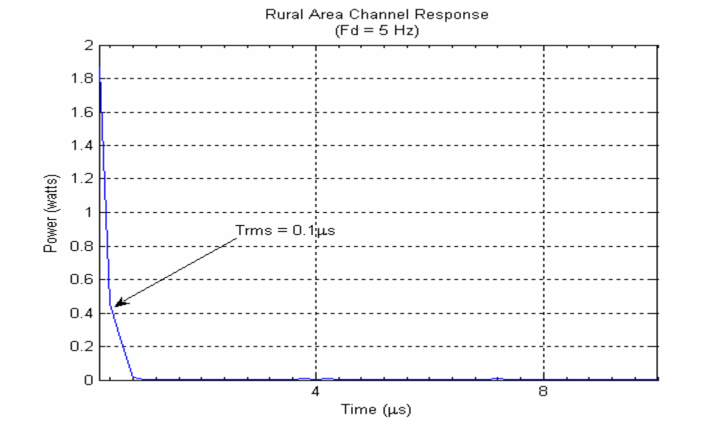

Figure (5): Channel Response at (f_D =5 and 100 Hz)

In order to have a better insight to the delay spread, a 2D plot of the channel response in time domain is shown in Figure (5), the figure shows that there is no resolvable multipath signals and this leads to higher variation in the strength of the received signal due to the constructive and destructive addition imposed on the received signal, this implies that the channel fading process is flat.

Referring to equation (2.1) the delay spread T_m = 0.5μs, however equation (2.3) is the most preferred to define the delay spread in terms of T_{rms} which equals 0.1 μs, Figure (5) shows that the spreading behavior of the channel in the time domain do 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, 3GPP Rural Areas tend to be flat fading channels where the signal duration is less than T_{rms} of the channel, T_s = 0.2μs >> T_{rms} = 0.1 μs, and the signals bandwidth is greater than coherence bandwidth of the channel B = 5 MHz >> B_c = 10 MHz.

Table (2) concludes the main properties of the 3GPP Rural 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}	0.1 μs	0.1 μs
Coherence Bandwidth B_c	10 MHz	10 MHz
Fast Fading	No	Yes
Slow Fading	Yes	No
Flat Fading	Yes	Yes

Table (2)

3. Conclusion:

3GPP Rural Area channel model is used to measure the performance of different systems, this paper showed that the channel impose a slow fading effect at f_D = 5 Hz and fast fading at f_D = 100 Hz these effect is caused by 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 system the channel tends to be a flat fading channel where the signal bandwidth is less than the coherence bandwidth of the channel.

A brief acknowledgement section may be included here.

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