PERFORMANCE MEASUREMENTS OF 3G SYSTEMS USING A RADIO CHANNEL SIMULATOR

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Abstract *In former narrowband systems the multipath fading has been an enemy to the system. Modern wideband communication systems like UMTS try to exploit the multipath phenomenon of the radio channel. Thus radio channel is a crucial part of the 3G test environment, which places great demands on understanding the radio channel well. This paper presents the 3GPP channel models and how radio channel simulator can be used in 3G conformance test systems. Test systems consist of System Simulator, Radio Channel Simulator, Noise Generator and User Equipment.*

Keywords Radio Channel Simulator, 3G, Performance

1 INTRODUCTION

In every wireless communication system 2G, 3G or any other, the surrounding environment defines the radio channel conditions. Radio channel simulators are used to reproduce this environment under laboratory conditions. The channel models inside simulator describe the environment. Figure 1 illustrates typical urban environment. Picture shows that at different mobile locations the radio channel conditions are different. In the case of 3G the key interest point of the channel is the impulse response. It describes delay and mean amplitude of each path. As an example one impulse response which is measured using channel sounder is shown in Figure 2. The 3G system tries to exploit the change in the channel. 3G receiver is typically based on RAKE technique, meaning that it measures the channel impulse response shown in Figure 2 and adjusts the receiver parameters accordingly. The delay resolution of the 3G receiver is much less than shown in Figure 2. RAKE receiver fingers are allocated on each resolved path in the impulse response. Maximum number of signal paths that can be used for receipting the signal is the number of fingers in the receiver. RAKE receiver has two main algorithms to react to the radio channel delay profile are finger allocation and finger tracking. Due to the time variancy of the channel it is very important to test these algorithms with as realistic channel models as possible. 3 GPP specifies two special models to test the basic functionality of these algorithms.

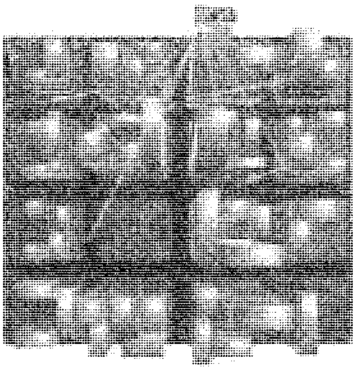

Figure 1: Time variant channel

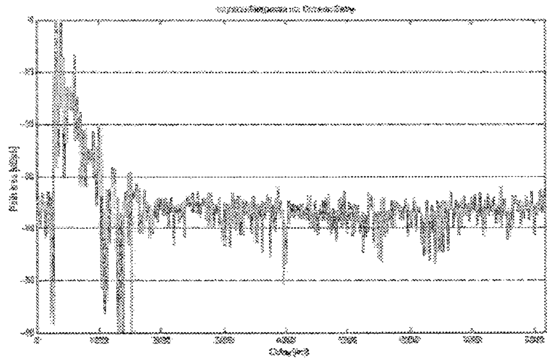

Figure 2: Channel impulse response measured with sounder

One of the most important elements in testing is repeatability. This places high demands on simulator accuracy. Digital radio channel simulator introduces high accuracy on phase, delay and amplitude, this together with accurately pre calculated channel models enable repeatable tests.

This paper is organised as follows: Section 2 introduces the 3 G channel models and common test setups. In Section 3 discusses how PROPSim C2 wideband radio channel simulator is used on 3G conformance test environment. Channel modelling tool is presented. An example how PROPSim C2 digital radio channel simulator is connected to 3G test system is discussed.

2 TEST ENVIRONMENT

3G test environment has four key elements, SS (System Simulator),UE(User Equipment), Noise generator and digital radio channel simulator. In this paper we focus on the digital radio channel simulator. Typically simulators are system independent and therefore applicable for any standard as long as the simulator bandwidth and delay accuracy are adequate. Simulator is used for generating required radio channel conditions specified in different standards. Channel conditions are specified with channel models.

2.1 Channel models

Channel models define the delay spread, fading distribution and average amplitude of each path and mobile speed of the channel. There are several standards on channel models in 3G area. 3 GPP has specified standard [1]&[2] and deployment models [3], 3GPP2 has models and also ITU has specified their own set of models.

This paper focuses on the 3 GPP standard and deployment models. In standard models there are seven statistically defined models each of them having different fading characteristics. Case 1 consist of two paths one on 0 ns with relative power of 0 dB and other on 976 ns with relative power of –10 dB, both have Rayleigh fading with classical Doppler spectrum. Mobile speed in this model is 3 km/h. Because the second path is significantly lower than the first one it has very little significance in the signal reception. Fading is hence almost flat and duration of the deep fades is long resulting high BER figures. 3G receiver can resolve 1/BW delay differences, thus the path delay difference is approximately 260 ns. Case 2 has three equally high amplitude paths with two short delays and one long delay. This model tests whether receiver is able to find the long delay. In this case this path would significantly increase the received signal energy and is therefore of interest. Case 3 has four paths separated by one chip length with amplitudes 0,-3,-6,-9 dB respectively. The model speed is 120 km/h. This tests receivers capability to resolve multipath components at high speed. Finding all of the components improves the quality of the received signal. Case 4 is otherwise same as case one, but strength of the second path is equal to the strength of the first. This model results deep fading notches about 1 MHz intervals on the frequency domain when paths are equally strong. Case is used on TPC (Transmit Power Control) measurements. Case 6 is same as case 3, but speed is 250 km/h. Basically this test is to ensure that receiver works also in high speed train environments.

In addition to the statistically defined models there are also two dynamic channel model cases Moving and Birth-Death model. Main difference to statistically defined models is that delay is not constant. These models are specially designed for RAKE receiver testing. Moving propagation is defined as follows [1]: "The moving propagation condition has two tap, one static, Path0, and one moving, Path1 as shown in Figure 3. The time difference between the two paths is according Equation 1. The taps have equal strengths and equal phases.

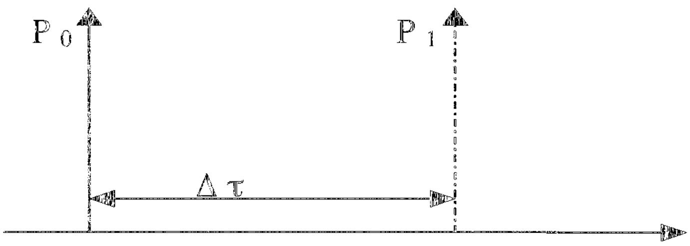

Figure 3: The moving propagation conditions

$$\Delta\tau = B + \frac{A}{2}\left(1 + \sin(\Delta\omega \cdot t)\right) \qquad (1)$$

The parameters in the equation are shown in table 1

Table 1

Parameter	Value
A	5 μs
□	1 μs
□ω	$40*10^{-3}$ s^{-1}

"

From the equation 1 and Table 1 parameters, model repetition interval 157 s , can easily be calculated. Moving model is used for RAKE receiver finger tracking algorithm testing. Delay is sliding sinusoidally and has thus variable sliding speed.

Birth Death is defined in [1] as follows: "The dynamic propagation conditions for the test of the baseband performance is a non fading propagation channel with two taps. The moving propagation condition has two taps, Path1 and Path 2 which alternate between 'birth' and 'death'. The positions the paths appear are randomly selected with an equal probability rate and is shown in Figure 4.

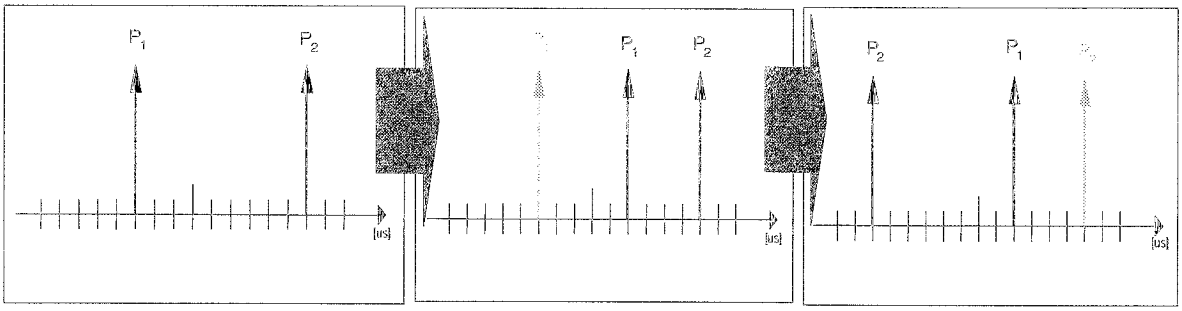

Figure 4: **Birth death propagation sequence**

1. Two paths, Path1 and Path2 are randomly selected from the group [-5, -4, -3, -2, -1, 0 ,1, 2, 3, 4, 5] µs. The paths have equal magnitudes and equal phases.

2. After 191 ms, Path1 vanishes and reappears immediately at a new location randomly selected from the group [-5, -4, -3, -2, -1, 0 ,1, 2, 3, 4, 5] µs but excludes the point Path2. The magnitudes and the phases of the tap coefficients of Path 1 and Path 2 shall remain unaltered.

3. After an additional 191 ms, Path2 vanishes and reappears immediately at a new location randomly selected from the group [-5, -4, -3, -2, -1, 0 ,1, 2, 3, 4, 5] µs but excludes the point Path1. The magnitudes and the phases of the tap coefficients of Path 1 and Path 2 shall remain unaltered.

4. The sequence in 2) and 3) is repeated."

The purpose of the Birth-Death model is to test RAKE receiver finger allocation algorithm. Both of these algorithms are part of the baseband signal processing and require the test conditions in very early design phase.

Deployment models are based on COST 259 research forum proposals. The main idea of the models is to try to model the real world channel conditions by statistics of channels. The occurance of these channel conditions are defined with probability densities. The probability densities are mainly functions of two parameters, environment and distance. COST 259 working group has proposed definitions for distance to be Macrocell, Microcell and Picocell. Macrocell includes environments like urban, rural area and hilly terrain. These are derived from the earlier GSM specification. Picocell is typically indoor environment which could be characterised as eg. Open lounge.
Deployment models defined in [3] are used for development purposes. Deployment models consist of 20 taps each. Reason for high tap count is to ensure that correlation properties in the channel in the frequency domain are realistic.
Outside standards there are plenty of different kind of models available who are trying to model the radio channel as realistic as possible. In [4] it is stated that Vehicular B model which has 6 paths with ~4Mcps and coherence bandwidth of 53 kHz, receiver could resolve up to 78 paths. Thus the more paths are simulated the more realistic the environment is.

2.2 3GPP test setups

3 GPP standard specifies three example test system setups for terminal and one setup for base station measurements where fading simulator is used. However also the static condition can

be added to these cases to minimize amount of setups needed. Figure 5 shows one of the test setups. This particular connection is mostly used and therefore chosen here as an example. Test setup is built with RF combiner, duplex filter (FDD), Noise generator, RF attenuators, SS (system simulator) and UE (user equipment). Real setup may vary according to different test equipment from different manufacturer. The other setups can be found from [1] Annex A and [2] annex B.

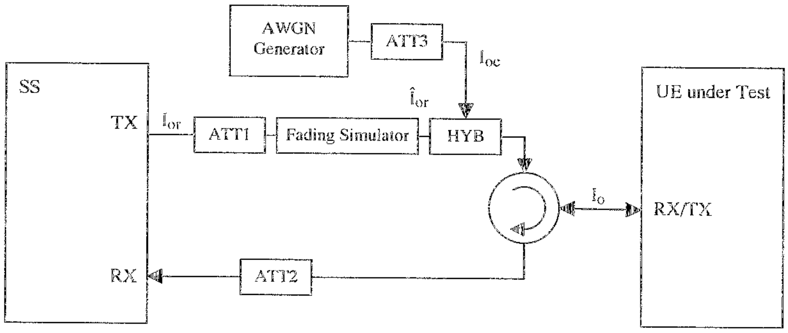

Figure 5: Connection for Multi-path Fading Propagation Test

This setup is used in most of receiver performance measurements. Test cases vary from the SS parameters point of view depending on the channel of interest. Main parameters are power levels and data rates. In the test setup the total channel power levels are defined to the UE antenna connector.

3 PRACTICAL CHANNEL MODELLING AND CONNECTIONS

There are several commercially available radio channel simulators on the market. Some of them have analog implementation some digital. In this section PROPSim C2 wideband radio channel simulator is introduced. PROPSim C2 is a digitally implemented wideband radio channel simulator. It has two independent channels each having 30MHz bandwidth. It also includes internal AWGN noise source. Channel models are defined by software.

The simulator has RF, Analog Baseband (ABB), and Digital Baseband (DBB) interfaces. The DBB interface enables also non-real-time (off-line) simulations. Table 2 summarizes the hardware specifications of the PROPSim C2 simulator.

Table 2. Hardware Specifications of PROPSim C2

Item	Specification
Number of channels	2
Simulation interfaces	RF, ABB and DBB
RF center frequency	350 MHz ... 6 GHz
RF bandwidth	30 MHz
Maximum delay	400 µs
Maximum Doppler shift	23 kHz

PROPSim C2 is commercially available, and is provided by Elektrobit Ltd., Finland (see Figure 6). More information about PROPSim C2 can be found from PROPSim web site [5].

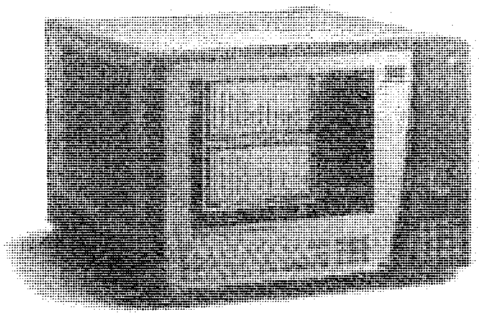

Figure 6: PROPSim C2 digital wideband radio channel simulator

3.1 Channel modelling

Radio channel simulator usually includes some kind of channel model editor. The editor is used to create environments specified in standards. Figure 7 illustrates channel model editor of PROPSim C2 wideband radio channel simulator. User can define desired number of paths and specify parameters to each path. Main parameters are delay, average amplitude, amplitude distribution and Doppler shape. Each path can have either fixed delay or dynamic delay. If dynamic delay is chosen a delay function can be selected. There are three functions available: linearly sliding, sinusoidally sliding or 3GPP standard hopping. In sliding delay function user can define the start and stop delay values and the period time. In hopping delay user can define delay positions and the state duration time. Hopping delay function is always implemented as specified in 3GPP. Typically editors are only capable of generating static delays. Average amplitude can be defined to each path as well as amplitude distribution. This tool includes the most common amplitude distributions. Some distributions have additional parameters like angle, which are defined in distribution parameters field. Finally for Rayleigh fading, Doppler spectrum shape can be separately defined.

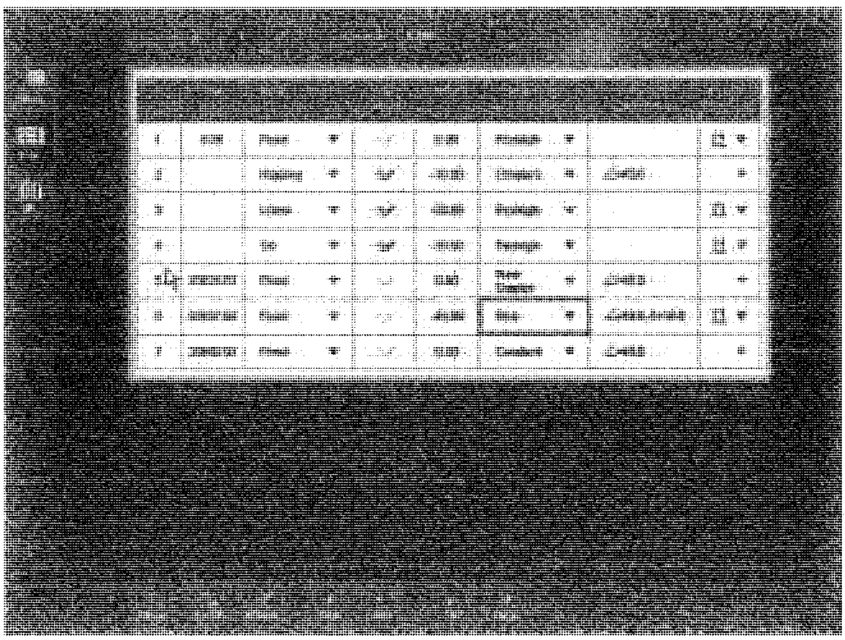

Figure 7: PROPSim C2 Channel model editor

Some test cases require use of two channels, the editor in PROPSim C2 supports two channels. It also allows user to define amplitude correlation between channels. By default channels are non correlating. Editor is designed so that any 3GPP channel model can be produced, but it is by no means limited to that. Modifying standard models and creating new non standard models is obviously possible as well.

In order to make comparison between different performance measurements, test system must be able to repeat itself, even after a long period of time. Digital implementation and precalculated models make this possible. To demonstrate the repeatability, two separate simulators were initialized with same RA120 deployment model. They were run to certain impulse response and frequency response was measured with network analyzer. In **Figure 8** & **Figure 9** one can clearly see that frequency responses are equal.

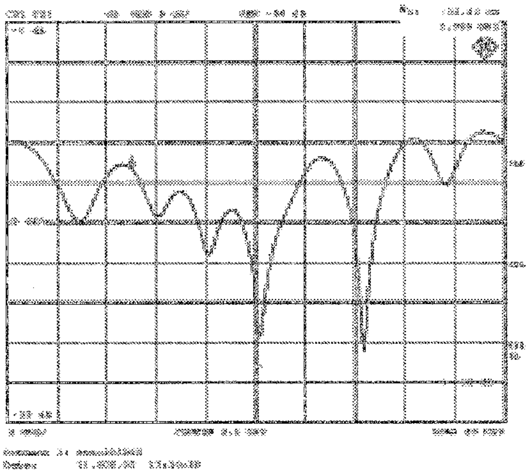

Figure 8: Frequency response Device 1

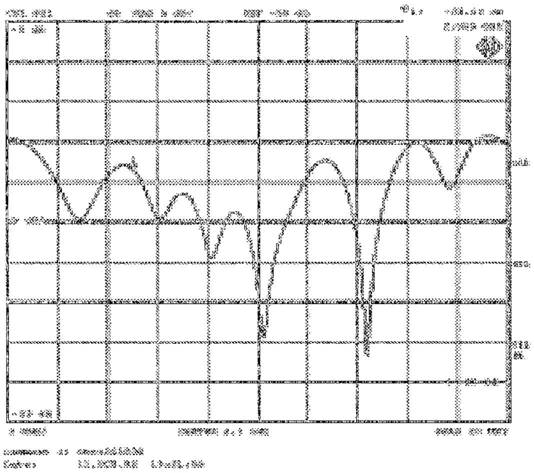

Figure 9: Frequency response Device 2

3.2 Simulator quality aspects

One quality measure of the statistical channel models is defined by Level Crossing Rate (LCR). This figure can be used both on hardware and software channel simulators. In Figure 10 a statistical analysis is made for one tap classical impulse response sequence. Informative requirements for **level crossing rate** are given as a maximum allowed deviation from theoretical values (10). Maximum deviation is 10 % from theoretical values on range 3 dB above to 30 dB below the mean power level.

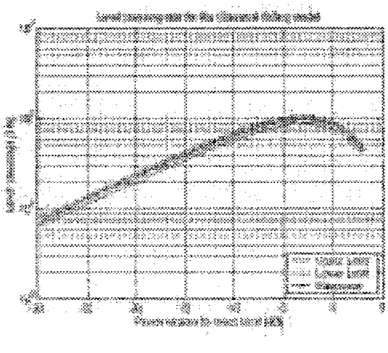

Figure 10: Level crossing rate for classical model

LCR describes how many crossings happen per second at each power level relative to the mean level. As the curve in Figure 10 shows most of the crossings are close to the mean power as they should.

Another quality measure is the power spectral density of classical Doppler shape. There are two requirements for **power spectral density**. The power difference

$$S(\pm f_{\max}) - S(0) \geq 6dB$$

and

$$S(\pm f_{\max}) - S(f) \geq 30dB, \qquad \text{when } |f| > 1.5 f_{max}.$$

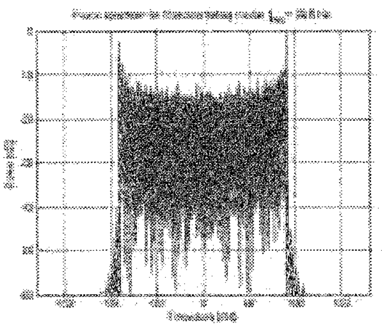

Figure 11: Simulated power spectral density of classical fading model

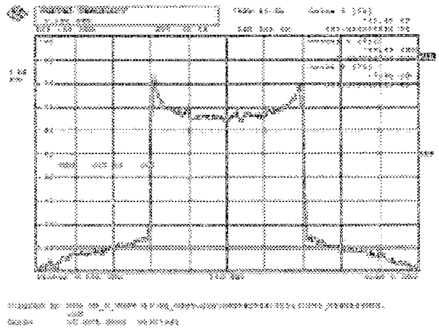

Figure 12: One tap classical fading with PROPSim C2

In addition to these statistical parameters also simulator linearity is important. Simulator is not allowed to distort the signal. Especially on wideband systems this has significance. Typically the performance close to the operating band side is not as good as in the middle of the band due to filtering etc. Thus having simulator with much wider bandwidth than application is beneficial.

3.3 Connections

As discussed in section 2 connections on the specification are only informative. Figure 13 illustrates how PROPSim C2 is connected to the example test connection described in Figure 5.

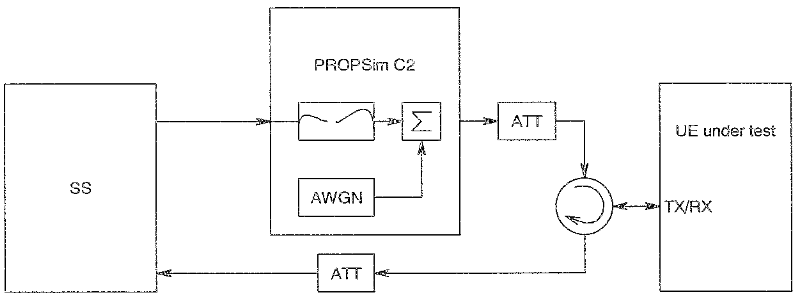

Figure 13: Multipath propagation test case connection with PROPSim C2

The SS feeds the signal to channel simulator channel one. Input level in simulator is set according to the power levels fed in. Input level setting consist of two parts average amplitude and crest factor. Desired channel model is chosen. Noise generator is set on and desired S/N is defined. To obtain the correct absolute signal levels output gain setting is tuned until desired level is reached. Before summing the noise signal is measured to ensure that define S/N ratio stays constant. Measurement is defined so that accuracy requirements for S/N in conformance testing are met.

CONCLUSION

This paper gives an overview on the 3GPP standard and deployment channel models. Key test connection is presented. PROPSim C2 wideband radio channel simulator is introduced. Channel modeling and accuracy aspects are generally discussed. The practical connection example proved that multipath test case setups can be simplified and hence made more robust.

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