

RESEARCH ARTICLE

Development of a MATLAB Toolbox for Mobile Radio Channel Simulators

D. S. De Silva

*Department of Electrical and Information Engineering, Faculty of Engineering,
University of Ruhuna, Hapugala, Sri Lanka*

Abstract: A profound knowledge of mobile radio channels is required for the development, evaluation, and also assessment at practical conditions of present and future mobile radio communication systems. The modelling, analysis, and simulation of mobile radio channels are important key area in current context. In addition to that, knowledge of channel behaviour in mobile radio communication is extensively recommended for the study of transmitter/receiver performances under different propagation scenarios. Our intention in this research work was to develop various kinds of mobile fading channel simulators using MATLAB and embed them into MATLAB software as a toolbox. Implemented channel simulators were combined MATLAB as a toolbox which users can easily select well-known channel models to test and to study the performance of mobile communication systems. It gives better support for the new users to work on the developed channel simulators, run the test procedures as well as parameter computation. The toolbox contains channel simulators for simulating non-stationary land mobile satellite channel, spatial shadowing processes, MIMO channels, multiple uncorrelated Rayleigh fading channels, mobile to mobile channel, frequency hopping channels etc. Set of test procedures were developed such as the autocorrelation function ACF, average duration of fades ADF, the probability density function PDF, and the level-crossing rate LCR etc., in order to test and to confirm the correctness of the implemented channel simulators. Proposed new algorithms to compute the model parameters of the channel simulators were also implemented in the toolbox to enable the parameterization of the channel simulators under specific propagation conditions. Some of the simulation models were implemented based on specification of GSM system by CEPT-COST 207.

Keywords: Matlab toolbox, parameter computation methods, Mobile fading channel simulators, Performance tests, Deterministic channel modelling

Introduction

Classical methods of modelling the fading behaviour of mobile radio channel are characterized by modelling of the transmission link between a base station and a mobile station (Pätzold, 2011). In the early stages of channel modelling (Clarke, 1968), the aim was to characterize the statistical properties of real-world channel mainly with respect to the probability density function of the channel's envelope. The time characteristics, and later the frequency characteristics of the mobile radio channel, have been included in the design procedure only to a limited degree. Modern methods of channel

modelling pursue to characterize the envelop fading regarding the first order statistics and the second order statistics, which include the level crossing rate and average duration of fade (Pätzold, 2011; Clarke, 1968). Following scientifically approved steps are required to get a fitted model compare with the reference model. First of all, a concrete phenomenon or case must be presented. The simulation model is usually derived from the underlying reference model or directly from measurements of physical channel. Then, measurements should be taken in order to specify the physical aspects.

*Corresponding author: dadallages@yahoo.com

The usefulness and importance of the reference model and corresponding simulation model is ultimately judge on how well their statistical properties can be matched to the statistical properties of specified or measured channels. Thus, we try to minimize the error modelling as much as possible to achieve the best match. These relationships will accompany for all channel models.

Materials and methods

MATLAB software was used to develop channel simulators. Mainly, most of the channel model simulators are implemented based on the sum-of-sinusoids principle which is first introduced by Rice and then developed later. Starting from the idea that each signal can be expressed under sum-of-sinusoids, assumed that any model type is able to be implemented following the sum-of-sinusoids principle (Pätzold, 2011). As it's well aware, when using the Rice method, assumed that numbers of sinusoids are infinite. But in real-world, consider N as small as possible aiming to let the implementation of the simulation realizable. This principle can be applied in any kind of simulation model. $c_{i,n}$ - gain Path. The simulation models are based on the

principle of deterministic channel modelling. The principle of deterministic channel modelling consists of the following steps to proceed (Pätzold, 2011; Pätzold, 2000).

Step 1: Starting point is the reference model; based on one or several Gaussian processes, each with prescribe autocorrelation function.

Step 2: Derive a stochastic simulation model from the reference model by replacing the Gaussian process by sum-of sinusoid with fixed gain, fixed frequency, and random phases.

Step 3: Determine a deterministic simulation model by fixing all model parameters of the stochastic simulation model including the phases.

Step 4: Compute the model parameters of the simulation model by fitting the relevant statistical properties of the deterministic (or stochastic) simulation model to those of reference model.

Step 5: Perform the simulation of one (or some few) sample functions (Deterministic processes).

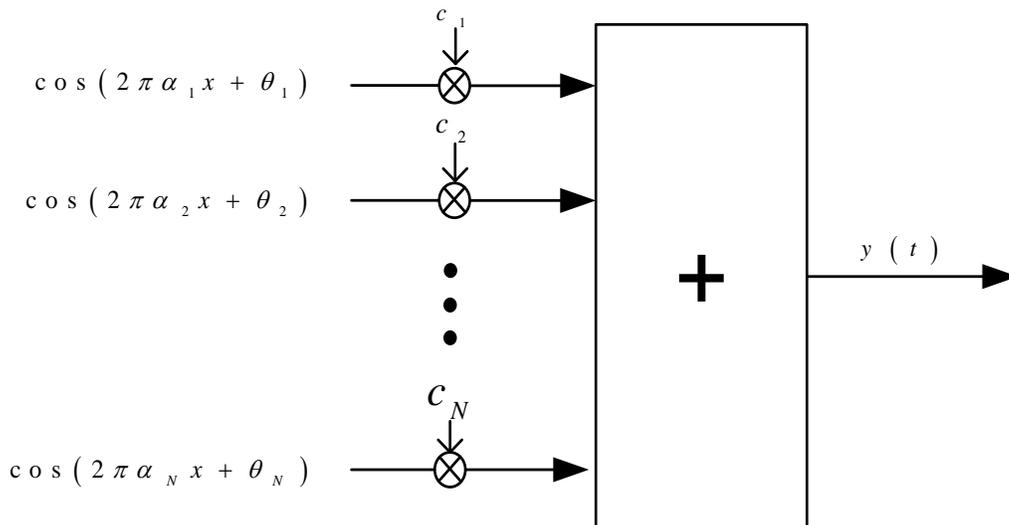


Figure 1. An example of sum-of-sinusoids principle

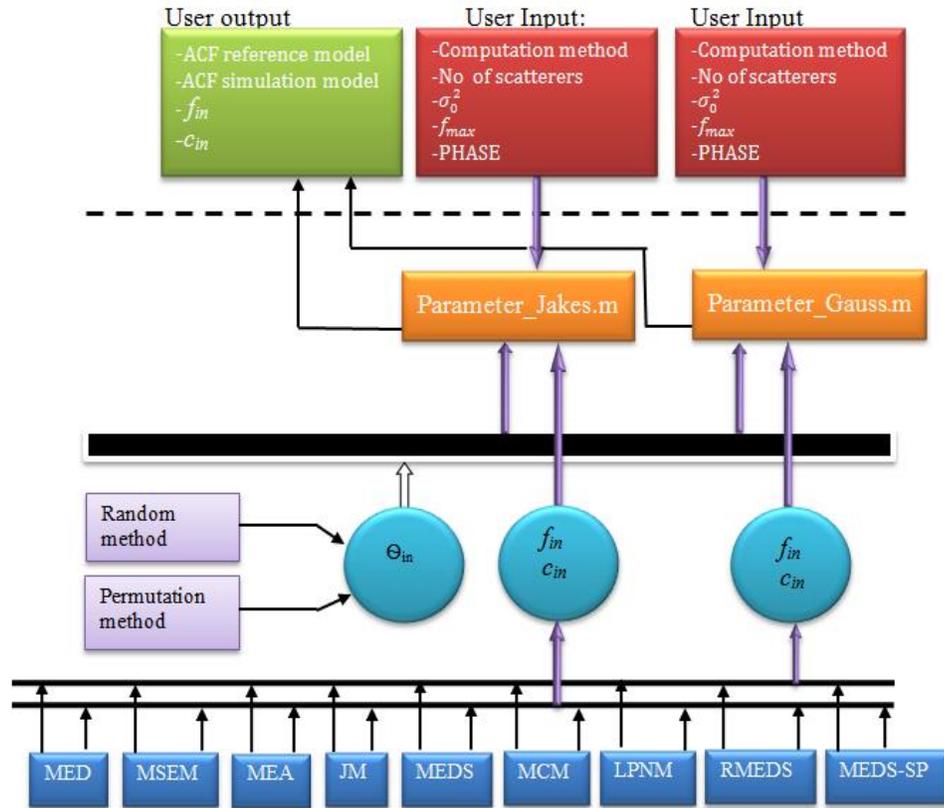


Figure 2. The implementation diagram of the parameters computation methods for the frequency-non-selective channel

Results and Discussion

Figure 2 illustrate the parameter computation model for different parameter computation methods (Pätzold, 1997). Computation is done according to user preferences and computed channel parameter can be used for channel simulators to observe the performances of the channel. Under this research work Different fading channel simulators which were implemented. The first part consisted with the implementation of the real world land mobile satellite (LMS) channel based on the extended Suzuki process Type I (Pätzold, 2006; Li, 2002; Pätzold., 2000). Second part consist with spatial channel simulator and it was implemented based on some adequate models like Gudmundson, Butterworth and Gauss models (Pätzold , 2006). The third part of this work consists with MIMO channel simulators (Pätzold, 2006). Under this, different procedures for finding the models parameters under different scenarios (one ring, tow ring and elliptical model) were implemented. It should be noted that the models

presented here are the summary of the literature reviewed in this research work. After implementation of the MIMO channel models; modelling of the multiple uncorrelated Rayleigh channel simulator was implemented (Pätzold, 2006). Final section of the channel modelling was implementation of the frequency hopping channel simulator model (Y. R. Zheng , 2002; Pätzold, 2009). It is made clear that for each simulator, testing functions were implemented such as time ACF (autocorrelation function), CCF (cross correlation function), etc. (Pätzold, 2006). and examined the correctness of the simulator with its reference model or with the measurement model to make sure fittingness. For comparative purposes, we have also plotted the performance curves for ACF, CCF, PSD etc.

As an example frequency hopping Simulation model was implemented based on the rural area profile specified for GSM system by CEPT-COST 207 (Pätzold, 1997). Frequency hopping in GSM is changed with every TDMA frame of duration 4.615ms.

$$c_{i,n} = \sigma_0 \sqrt{\frac{2}{N_i}}, \quad (1)$$

$$f_{i,n} = f_{max} \sin \left[\frac{\pi}{2N_i} \left(n - \frac{1}{2} \right) \right], \quad (2)$$

$$\tilde{\gamma}_{\mu_i \mu_i}(\tau, \chi) = \sum_{n=1}^{N_i} \frac{c_{i,n}^2}{2} \cos(2\pi f_{i,n} \tau + 2\pi \phi_{i,n} \chi), \quad (3)$$

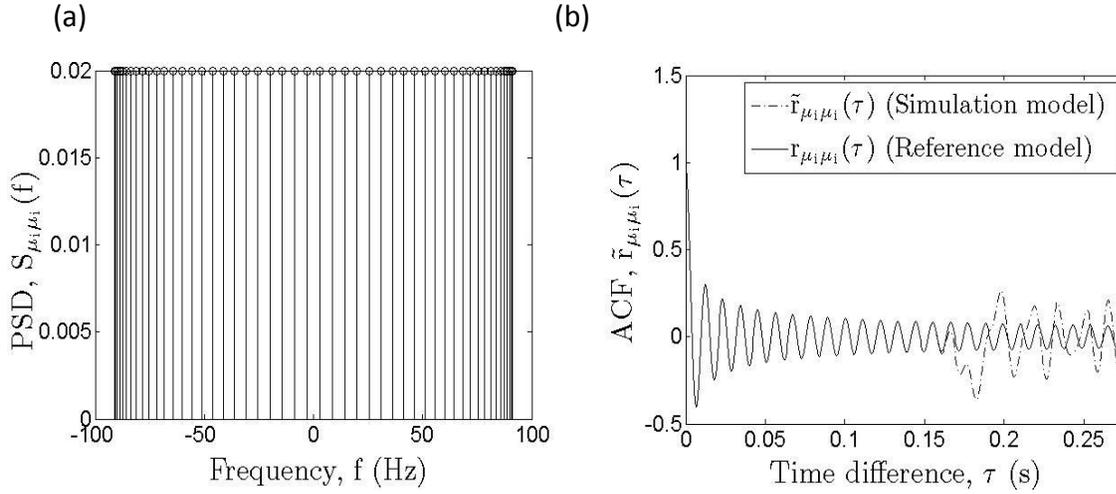


Figure 3. (a) PSD and (b) ACF of Jakes model using MEDS method.
 ($N = 20, \sigma_0^2 = 1, f_{max} = 91 \text{ Hz}$)

The resulting hopped output signal of the envelope illustrates the cross correlation function obtained for COST207 rural area for reference model and Simulation model. Parameter computation was done based on MEDS (Method of Exact Doppler Spread) (Pätzold, 2011). and parameters were defined in (1) and (2) for scatters component of $N = 20$. Figure 3 illustrates the power spectral density and autocorrelation behaviour under jakes model for parameter computation methods of MEDS method. ($f_{i,n}$ - Doppler frequencies, $c_{i,n}$ - gain Path, $\tilde{\gamma}_{\mu_i \mu_i}(\tau, \chi)$ - Auto correlation of simulation model, τ - Time delay, σ_0^2 - Mean power, N - Number of

scatters). It can be seen that the limited number of sinusoids N_i gives excellent approximation result for $\tilde{\gamma}_{\mu_i \mu_i}(\tau) \approx \gamma_{\mu_i \mu_i}(\tau)$ (ACF reference model and simulation model) in the interval $0 \leq \tau \leq N_i / (2f_{max})$ as show in Figure 4 for $N_i = 20$. Figure 5 shows close relation of the cross-correlation function of simulation model (3) ($\tilde{\gamma}_{\mu_i \mu_i}(0, \chi)$ and reference model $\gamma_{\mu_i \mu_i}(0, \chi)$ for $N_i = 20$. When the numbers of scatters (N) are increased it gives excellent approximation close to reference model.

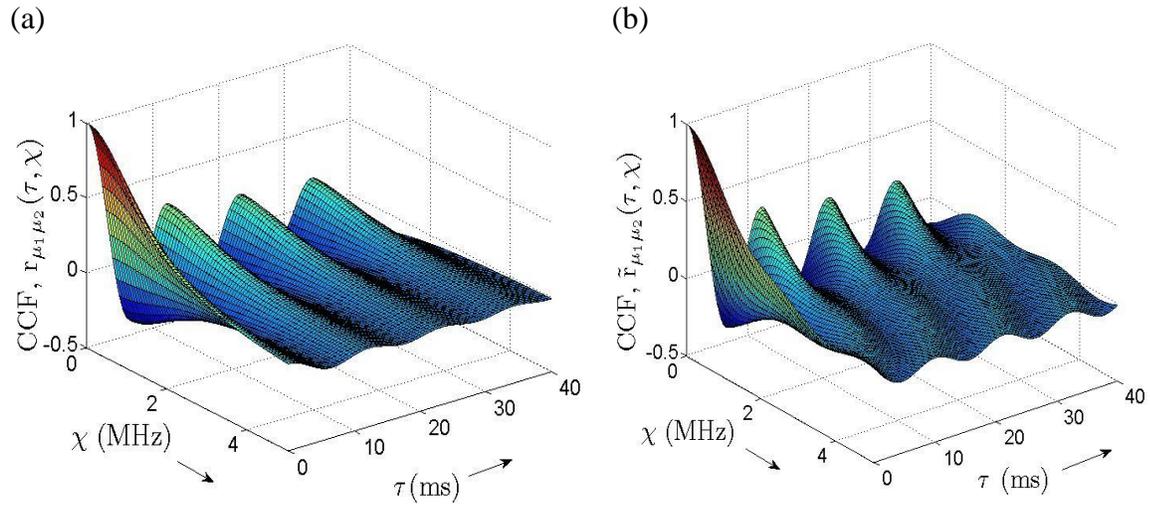


Figure 4. Cross correlation function obtained for COST207 rural area profile ($a = 0.1086 \mu\text{s}$, $\sigma_0^2 = 1$, $f_{max} = 91 \text{ Hz}$) (a) Reference model (b) Simulation model for $N_i = 20$

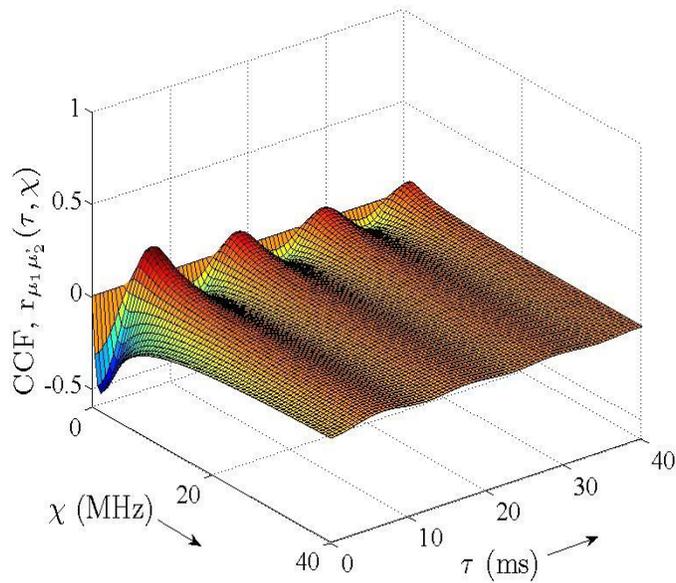


Figure 5. Cross-correlation function of reference model for COST 207 Rural area profile ($a = 0.1086 \mu\text{s}$, $\sigma_0^2 = 1$, $f_{max} = 91 \text{ Hz}$)

Conclusion

Mobile radio Channel simulators are essential component in the development and accurate performance evaluation of wireless systems. Efficient design and implementation techniques are important in the design and verification of the developing channel simulation model. Wireless communication systems must be designed to operate over radio channels for a wide variety of environmental and weather conditions. Numerous real-time test cases are applied to a new communication system before release the products to the market. Modelling of channel simulators is one of the important tasks during this process. Although MATLAB consist with few channel models they are not address for all parameter computation methods under different propagation scenarios. Developed simulation models are addressed for different propagation scenario with optimal parameter computations.

The mobile radio channel simulators allow the performance evaluation of mobile communication systems under controlled and repeatable conditions that would not normally be possible in actual field testing. It is important that such a channel model represents all of the relevant behaviour and properties of actual propagation environments as accurately as possible. Therefore these developed channel simulators are important for the test, the parameter optimization, and the performance analysis of mobile communication systems (Pätzold, 2011; Pätzold, 2004).

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