Simulation of Fading Channels using Different Tests

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Abstract — **The term *fading*, in the context of mobile communications, refers to the interference caused by the reception of numerous scattered copies of a given signal at an antenna. Fading can produce significant random variations of signal power –in the scale of 10s of dBs over fractions of a wavelength- and hence, can be extremely destructive to the signal. Therefore, in order to achieve reliable mobile communications, provisions must be considered to counter the effects of fading. Indeed, a first step towards this end is to understand these effects through producing models of and simulating this phenomenon.**

This paper discusses the development of an Object-Oriented MATLAB component that simulates the effects of fading, based on a somewhat simplified mathematical model. Clearly the simplified model might not present a very realistic view of the highly complex and random nature of fading; nevertheless, this simulation serves as an extremely useful research tool for comparing and measuring the effectiveness of different communication techniques.

Keywords- fading, scattered, signal, simulation

I. INTRODUCTION

Mobile communications and wireless network have experienced massive growth and commercial success in the recent years. However, the radio channels in mobile radio systems are usually not amiable as the wired one. Unlike wired channels that are stationary and predictable, wireless channels are extremely random and time-variant. It is channel causes an arbitrary time dispersion, attenuation, and phase shift, know as fading, in the received signal. Fading is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times.

Designers and engineers of mobile communications systems are faced with three main challenges, which are introduced by the communication channel: Path Loss, Shadowing and Fading. Path Loss refers to the decrease in signal power, which is mainly brought about by the physical distance between the communications devices. Shadowing takes

on a more local view and refers to the loss of power attributed to large obstacles such as hills and tall buildings. Finally, Fading, the main topic of this paper, takes on a yet more microscopic view and is concerned with the interference caused by the reception of numerous scattered copies of the signal at the antenna.

II.DESCRIPTION

2.1 A Brief Mathematical Model of Fading

The transmission of a band pass and narrowband signal to a mobile is modelled as a multipath channel.

In order to simplify our model we consider a special case with the following two properties:

1. Delay-Doppler power density is separable, i.e. we have 'two one dimensional functions to describe the scattering, rather than one two dimensional function. We then have where S is referred to as the Doppler spectrum.

$$sr(t) = \frac{sg(v)}{\sigma g} * pg(t)/\boldsymbol{\sigma g}$$

2. Scattering is isotropic, i.e. the power received by the mobile from all angles, is uniform.

$$Rg(\mathsf{T}) = \boldsymbol{\sigma} g2/\pi fd \ 1/sqrt \ (1- (v/fb) \ 2)$$

III. COMPONENT HIGH-LEVEL DESCRIPTION

3.1 Usage

Viewed as a 'black-box', the general usage scheme of the Fading Simulation Component is shown in the following diagram, where the input/output relationship.
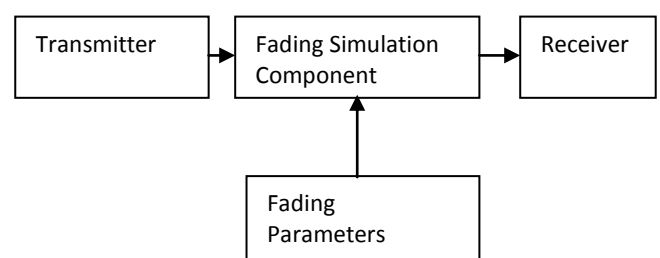
Figure3.1: Black-box view of the Simulation Component

The Fading Simulation receives the input signal s(t), adds simulated fading effects based on the Fading Parameters and outputs the signal y(t). The input signal s(t) is originated in a Transmitter, while the output signal y(t) eventually reaches a Receiver. The input and output of the component are in the form of arrays of complex numbers of an arbitrary length, containing the input and output samples respectively. In addition, the component could be used in real-time, in conjunction with another MATLAB program.

3.2 Structure

Internally, the Fading Simulation Component consists of a Tapped Delay Line (TDL) and a number of Complex Gain Generators.

3.2.1 The Tapped Delay Line

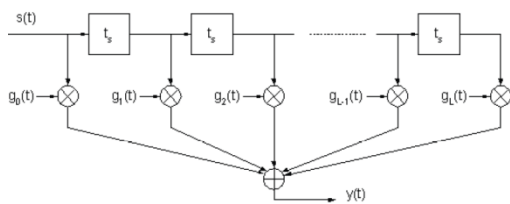The TDL structure is shown in the following diagram.

Figure 3.2.1.1: Tapped delay line

The TDL generates multiple time-shifted copies of the input signal, each of which is weighted by a complex gain (which is, in turn, generated by the complex gain generator.)To mimic, the TDL is, in effect, using discrete 'delay bins' of width ts=1/fs, where the complex gain corresponding to each bin reflects the weighted sum of the complex gain of all delayed signal copies that are included in that bin. Also, note that the Nyquist criterion requires *fs>2W*, where *W* is the bandwidth of Fading Parameters the signal plus the Doppler frequency (fD).

3.2.2 The Complex Gain Generator

The following three properties must hold for the complex gain generator:

1. Real and imaginary parts of the generated complex gain must be independent and Gaussian, having the same autocorrelation.
2. Different complex gain generators (corresponding to different taps in the TDL model) must be independent.
3. The autocorrelation function must be the one. Two of the most widely used methods for complex gain generation were implemented. These are Jakes Method and the method of Filtered White Noise.

a) Jakes Method

Basically, Jake's Method works by simulating the physical model of isotropic scattering. It assumes that there are *N* equispaced scatterers around the mobile, all with the same gain. However, the phase angle associated with each scatterer is chosen at random. The following equation is used by Jake's Method to generate complex gain samples:
Also, using Jake's Method is advantageous in that it can be run backward and forward in time with desired spacing, it has low computational load and is fairly simple.
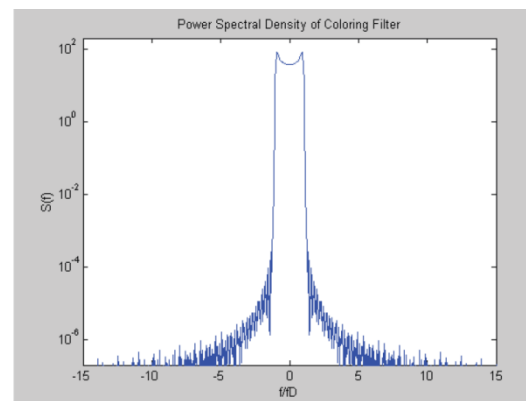
b) Filtered White Noise

Figure 3.2.1.2: Power spectral density of coloring filter

The method of Filtered White Noise achieves the desired power spectrum by generating white Gaussian noise samples and passing them through a spectrum shaping filter. Two independent white noise generators are used for the real and imaginary parts respectively.

IV. COMPONENT IMPLEMENTATION AND TESTING

As discussed before, the programming language chosen for this project was MATLAB. This is indeed a sensible choice because MATLAB is often the preferred language for creating communications simulations. Therefore, being in MATLAB, the component is available to a wide

range of applications. Another crucial decision made was to use the Object Oriented extensions of

MATLAB and create a modular and object-based program. As a result, this simulation consists of a number of subcomponents (or classes) that, on the one hand, form the Fading Simulation Component, and on the other hand, are independent enough to be used individually. This section describes the Object Oriented structure of the simulation, including relevant details regarding each subcomponent (i.e. class) of the internal structure.

4.1 Class description

This section describes the functionality of each of the classes listed above.

4.1.1 Complex Gain Gen: Complex Gain Generator Base Class Complex Gain Gen is an abstract class defining the common interface shared by all types of Complex Gain Generator classes. This common interface is simply based on the following facts about any Complex Gain Generator, regardless of class: other word, the interface of ComplexGainGen merely suggests that a Complex Gain Generator should be able to generate an array of complex gain samples. This only specifies *what* needs to be done; how this is done is not specified and is left for the derived classes to implement.

4.1.2 JakesGen: Complex Gain Generation using the Jakes Method JakesGen is derived from ComplexGainGen and implements the Jakes Method of Complex Gain Generation. JakesGen is a self-contained module, which can be used independently to generate complex gain samples.
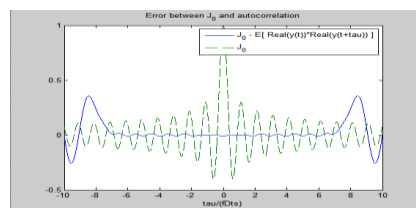
Figure 4.1.2.1: difference between actual and theoretical calculation

4.1.3 FWNGen: Complex Gain Generation using Filtered White Noise FWNGen is derived from ComplexGainGen and implements the Method of
Filtered White Noise. As stated before, FWNGen is a self-contained module, which can be used independently to generate complex gain samples. The main function of the FWNGen class is to provide an implementation for the generate member function derived from ComplexGainGen.

This implementation directly filters White Gaussian Noise samples to achieve the desired power spectral density. This is done through the Overlap-Add Filter Method] as described in the following flowchart:
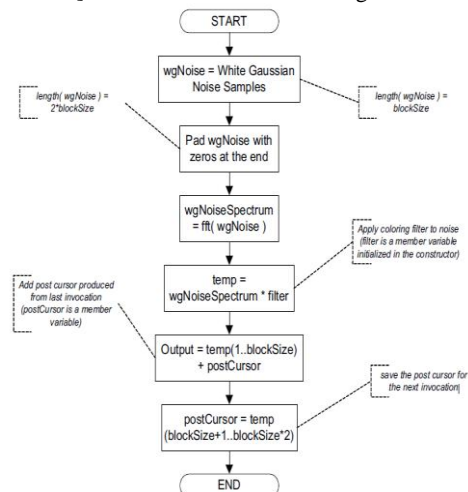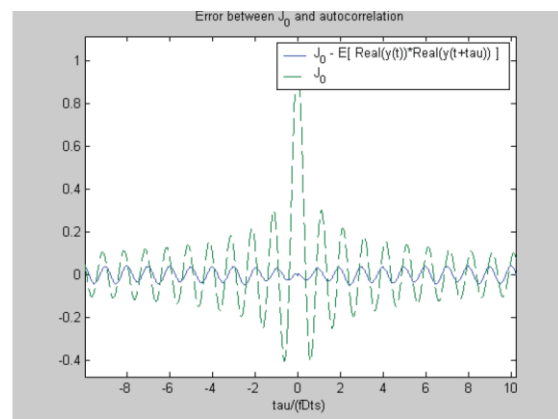

Figure 4.1.3.1: Creating the coloring filter for FWNGEN

Figure 4.1.3.2: difference between actual and theoretical calculation

4.2 TDL: Fading Simulation Example

Subsequent to performing unit testing on each of the Complex Gain Generators, we can put the whole system together for testing, which constitutes an actual Fading Simulation example. This is done by putting a known signal through the TDL and observing the results.

Sampling Frequency (fs)	320KHz
fD	1Hz
Number of Taps	8
Delay Spread	250us
Generator Block Size	1000
Number of Scatterers (JakesGen only)	25
Beta (FWNGen only)	10

In addition to the parameters above, we need to specify a Power Delay Profile. That is, we need to state what the complex gain power is at each tap of the TDL.
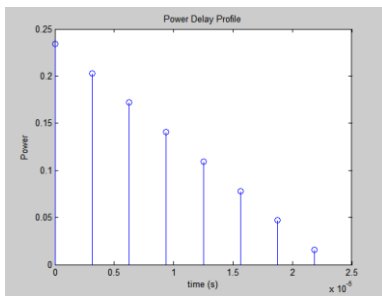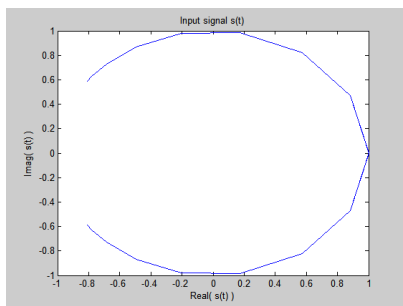
Figure 4.2.1: Power profile delay
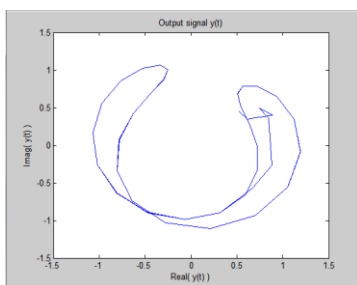

Figure 4.2.2: Processor input

Figure 4.2.3: Processor output

Depending on the processor utilisation we get the output of the processor showing the fading criteria.

V. CONCLUSIONS

The research and development carried out for the purpose of this thesis was focused on creating a Fading Channel Simulator in MATLAB. This simulation models a simplified view of the Fading phenomenon encountered in communications systems. By being embedded in other MATLAB programs, the simulation can prove to be very useful for measuring the performance of various communication techniques.

The work mainly consisted of creating a Tapped Delay Line structure to implement a time varying linear filter and also implementing two different techniques of Complex Gain Generation: The Jake's Method and The Method of Filtered White Noise. To this end, an Object Oriented architecture was designed, consisting of a number of autonomous classes, which can be used together in a system, or otherwise independently. Various advantages of this design such as Modularity and Extendibility were explored. Furthermore, extensive testing was carried out at the unit and also at the system level. These tests ensured that each component as well as the whole system performed as expected. The end result of this project is a MATLAB class library. In order to improve the performance of the various functions included, in the future, some or all of the functions could be ported to a more low level programming language such as C. Furthermore, additional Complex Gain Generator classes can be implemented to support other types of Complex Gain Generation.

VI. REFERENCES

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