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Date : 5 MAY 2006

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NUMERICAL SIMULATION OF COMMUNICATION CHANNEL WITH DIFFERENT TYPES OF FADING

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Signature	:	[signature]
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Date	:	5 May 2006

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Dedicate to

My parents, lectures, supervisor and friends.

Also to

Mohd Syahras Tani B Harimin (Aras)

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First of all, many thanks and gratitude to En. Muhammad Syahrir Bin Johal, my supervisor, for the guidance, the patience and the help that he gave me through the completion of this project.

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Muhammad Imran Bin Abin

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ABSTRAK

Projek ini bertujuan untuk membangunkan sebuah sistem simulasi untuk saluran perhubungan wayarles dengan kehadiran pemudaran yang berbeza. Objektif utama projek ini ialah untuk mengkaji kebarangkalian ralat pada penerima dan kesan kehadiran beberapa jenis pemudaran di dalam saluran perhubungan. Simulasi ini berupaya untuk menghasilkan isyarat pemudaran Rayleigh dan Rician. Isyarat yang dihantar akan dilemahkan sewaktu ia melalui simulasi. Program simulasi ini terdiri daripada simulasi sistem modulasi, penjanaan saluran pemudaran dan penilaian kebarangkalian ralat bagi isyarat yang diterima. Program ini termasuk sistem modulasi BPSK sebagai pelengkap kepada penghantaran isyarat. Pengkajian telah dilakukan terhadap taburan pemudaran Rayleigh dan Rician. Isyarat yang dihantar akan menerima kesan oleh kehadiran pemudaran dan gangguan hingar. Di akhir projek ini saya telah mendapat keputusan yang telah disasarkan.

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ABTRACT

The purpose of this project is to develop a numerical simulation of mobile communication channel with different types of fading using MATLAB software. The main objective of the project is to investigate the probability of error at the receiving end of the channel and effect of different types of fading. The simulator is capable of producing the Rayleigh and Rician faded signal. The signal transmitted will be attenuated as it goes through the simulator. The program proceeds in the simulation of modulation system, the construction of fading channel and the probability of error which determine the accuracy of the simulator. The program therefore includes a BPSK modulation system to complete the transmission of a signal. Distribution of Rayleigh and Rician has been studied. Signal transmission with effect of fading and noise is reported. In the last part of this project, the simulation system is observed to produce the result as expected.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

In overall, this project is based on the simulation of a communication channel with different types of fading in transmission channel.

In a communication system, a good bandwidth with a low bit error rate becomes the requirement that is most needed by a system designer. However, the occurrence of many types of fading in the communication channel cannot be avoided because of many obstacles such as buildings and trees. These obstacles cause the fading effect to the communication system.

There are many methods can be taken to increase the system performance. Modulation is one of the most popular techniques to control the bit error rate. But, we also need good information about the communication channel. So, the simulation of the communication channel is needed to test and estimate the bit error rate of the system to improve the communication system performance.

The simulation of communication channel is designed as circuits so that it can be simulated using one of the computer simulations software. The advantage of computer simulation is that it is not costly and flexible to produce the types of fading

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needed by a designer. This simulation is designed based on the magnitude and phase of Rayleigh and Rician fading. Similarly, the noise (AWGN) is also included in the communication channel.

1.2 Objective

The objective of this project is to study the characteristics for each type of fading such as Rayleigh and Rician fading in the communication channel.

One of the tasks of this project is to design a numerical simulation method with different types of fading (Rayleigh and Rician) using MATLAB.

The final objective is to study the performance of each type of fading occurs in the communications channels (Rayleigh and Rician).

The simulator can produce bit error rate (BER) for the communication channel based on the types of fading. From the BER result, the performance of each type of fading can be obtained.

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1.3 Scope

This project is focused to design simulation software that includes the design of a basic of communication system and its fading channel. Basically, the fading that is taken into consideration is Rayleigh distribution and Rician distribution. It also includes the noise generator.

The input data is a binary bit. Firstly, this simulation software produces the BER simulation of BPSK modulation with no fading.

After that, fading is added to the simulation software. The fading for this project includes Rayleigh and Rician fading. The result also produces the bit error rate of the communication channel when fading occurs.

The MATLAB software is chosen as a tool to design this communication channel. The advantage of using MATLAB software is that it is suitable for complex calculation of communication system equation. On the other hand, this software is easy to learn as compared to other softwares in the market.

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1.4 Methodology

This project is divided into three phase. The first phase is doing literature review on all the related information on communication channel especially for BPSK modulation, Rayleigh fading and Rician fading. The process also includes the information searching through the communication system books, journals, magazines, internet and others. This phase is very important because in order to develop the communication channel simulation, the author has to understand in detail all about communication channel characteristics.

In the second phase, the author starts to program the source code for this simulation. Firstly, the author starts with the simulation of communication channel with BPSK modulation with no fading as the main subprogram. In this phase, the simulation shows the bit error rate graph of the communication channel. After that, the Rayleigh and Rician fading are added to the simulation system. The last result of this simulation is the plot of communication channel performance with the prescribed situation.

The last phase of the simulation system is the performance testing of the simulation system. The graphs of all types of fading channels with respect to their performance in the communication system are analyzed in this part.

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CHAPTER II

LITERATURE REVIEW

2.1 Communication Channel

The communication channel system exists to convey a message. This message comes from the information source, which originates it, in the sense of selecting one message from a group of messages. The set of messages consist of individual messages which may be distinguished from one another. These may be words, groups of words, code symbols or any other prearranged units. Information itself is the one that is conveyed. The amount of information contained in any message can be measured in bits.

So, the communication system is used to communicate the source information to the users through the channel as a transmission media. The channel of communication systems includes microwave, cable, telephone line and others.

In this project, free space is used as the channel to the communication system simulation and the signal transmission is affected by different types of fading such as Rayleigh and Rician fading. On the other hand, the signal transmission is also attenuated by the preserve of Additive White Gaussian Noise (AWGN). The picture below shows the basic communication system block diagram.

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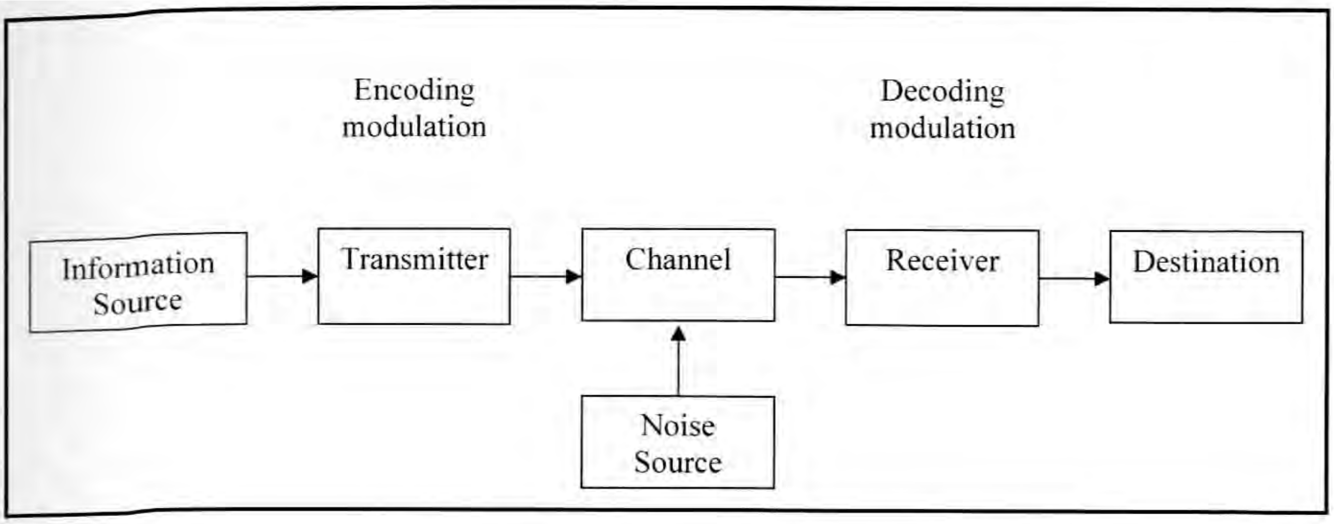

Figure 2.1: Block Diagram of communication system.

2.2 Multipath Fading

Radio waves propagate from a transmitting antenna, and travel through free space undergoing absorption, reflection, retraction, diffraction and scattering. They are greatly affected by the ground terrain, the atmosphere and the objects in their path, like building, bridges, hills, trees and others. These multiple physical phenomena are responsible for most of the characteristic features of the received signal.

In most of the mobile or cellular systems, the height of the mobile antenna may be smaller than the surrounding structures. Thus, the existence of the direct or line-of-sight path between the transmitter and the receiver is highly unlikely. In such a case, propagation is mainly due to reflection and scattering from the buildings and by diffraction over and around them. So in practice, the transmitted signals arrive via several paths with different time delays creating a multipath situation as in Figure 2.2.

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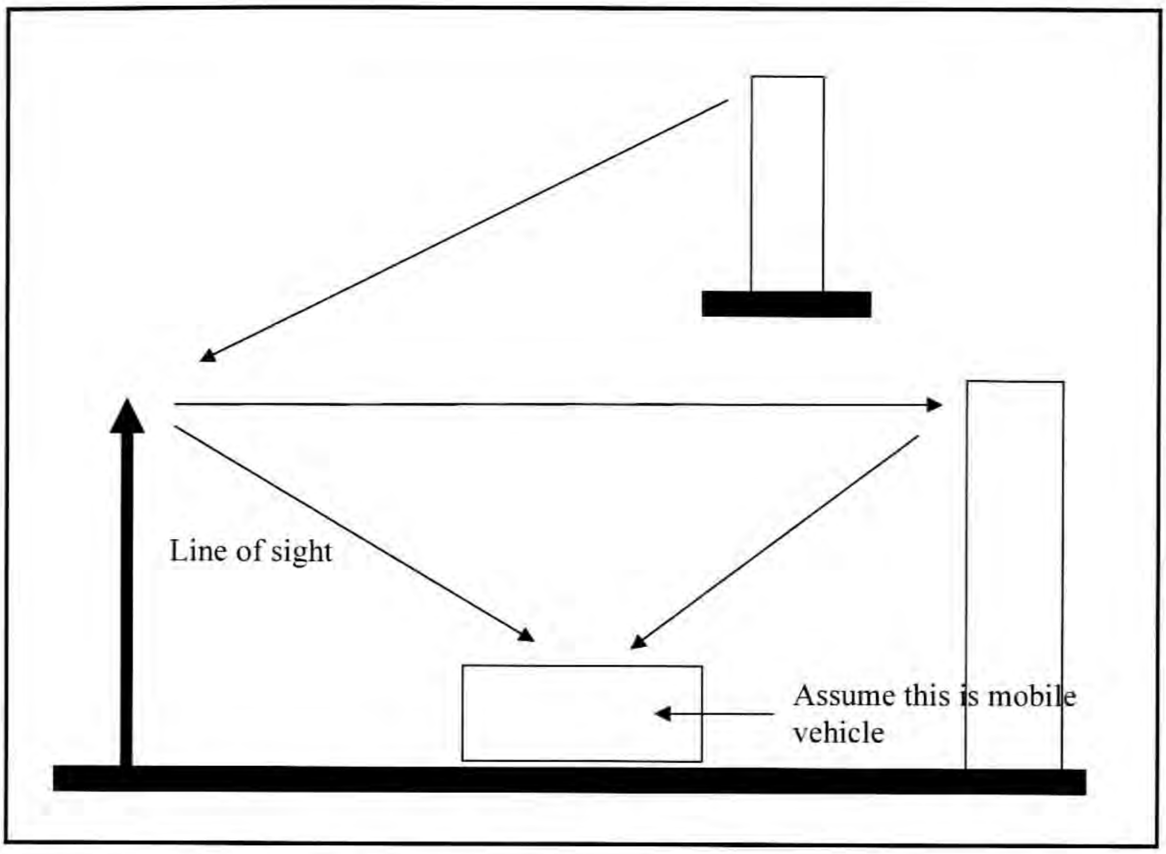

Figure 2.2: Mechanism of radio propagation in a mobile environment. A number of indirect paths and a line of sight path are shown.

2.3 Fading

At the receiver, these multipath waves with randomly distributed amplitudes and phase combine to give a resultant signal that fluctuates in time and space. Therefore, a receiver at one location may have signal that is much different from the signal at another location, only a short distance away, because of the change in the phase relationship among the incoming radio waves. This causes significant fluctuations in the signal amplitude. This phenomenon of random fluctuations in the received signal level is termed as fading.

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The short-term fluctuation in the signal amplitude caused by the local multipath is called small-scale fading, and is observed over distances of about half a wavelength. On the other hand, long-term variation in the mean signal level is called large-scale fading. The latter effect is a result of movement over distances large enough to cause gross variations in the overall path between the transmitter and the receiver. Large-scale fading also known as shadowing because these variations in the mean signal caused by the mobile unit moving into the receiver can experience several fades in a very short duration, or in a more serious case, the vehicle may stop at a location where the signal is in deep fade. In such situation, maintaining good communication becomes an issue of great concern.

Small-scale fading can be further classified as flat fading or selective, and slow or fast. A received signal is said to undergo flat fading, if the mobile radio channel has constant gain and a linear phase response over a bandwidth larger than the bandwidth of the transmitted signal. Under these conditions, the received signal has amplitude fluctuations due to the variations in the channel gain over time caused by multipath. However, the spectral characteristics of the transmitted signal remain intact at the receiver. On the other hand, if the mobile radio channel has a constant gain and linear phase is said to undergo frequency selective fading. In this case, the received signal is distorted and dispersed, because it consists of multiple versions of the transmitted signal, attenuated and delayed in time. This leads to time dispersion of the transmitted symbols within the channel arising from these different time delays resulting in intersymbol interference (ISI).

When there is relative motion between the transmitter and the receiver, Doppler spread is introduced in the received signal spectrum, causing frequency dispersion. If the Doppler spread is significant relative to the bandwidth of the transmitted signal, the received signal is said to undergo fast fading. This form of fading typically occurs for very low data rates. On the other hand, if the Doppler spread of the channel is much less than the bandwidth of the baseband signal, the signal is said to undergo slow fading.

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2.3 Types of fading

There are many types of fading that may occur in our real life mobile environment today:

i) Small – scale fading
   - Observed over distances of about half a wavelength.
   - Rayleigh
   - Rician

ii) Large – scale fading
   - Long term variation in the mean signal.
   - This is a result of movement over distances large enough to cause gross variations in the overall path between the transmitter and the receiver.

iii) Shadowing
   - These variations in the mean signal level are caused by the mobile unit moving into the shadow of surrounding objects like buildings and hills.

iv) Path loss
   - Signal attenuation between transmitter and receiver.

In this simulation project, the author is only focused on the small-scale fading, that is for the Rayleigh and Rician fading.

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2.4 Rayleigh Fading

As mentioned before, Rayleigh fading occurs when the radio wave transmitted from the base station radiates in all directions, including reflected waves that are reflected off various obstacles, different waves, scattering waves from the base station to the mobile station. Since there is no direct path for the Rayleigh fading or there may also occur with certain special situation but in very small values. This is the difference between Rayleigh fading and Rician fading. In this case, since the path lengths of direct paths, reflected, diffracted and scattering waves are different, the time each takes to reach the mobile station will be different. This situation makes a delay time situation. Figure 2.3 below shows the Rayleigh fading concept.

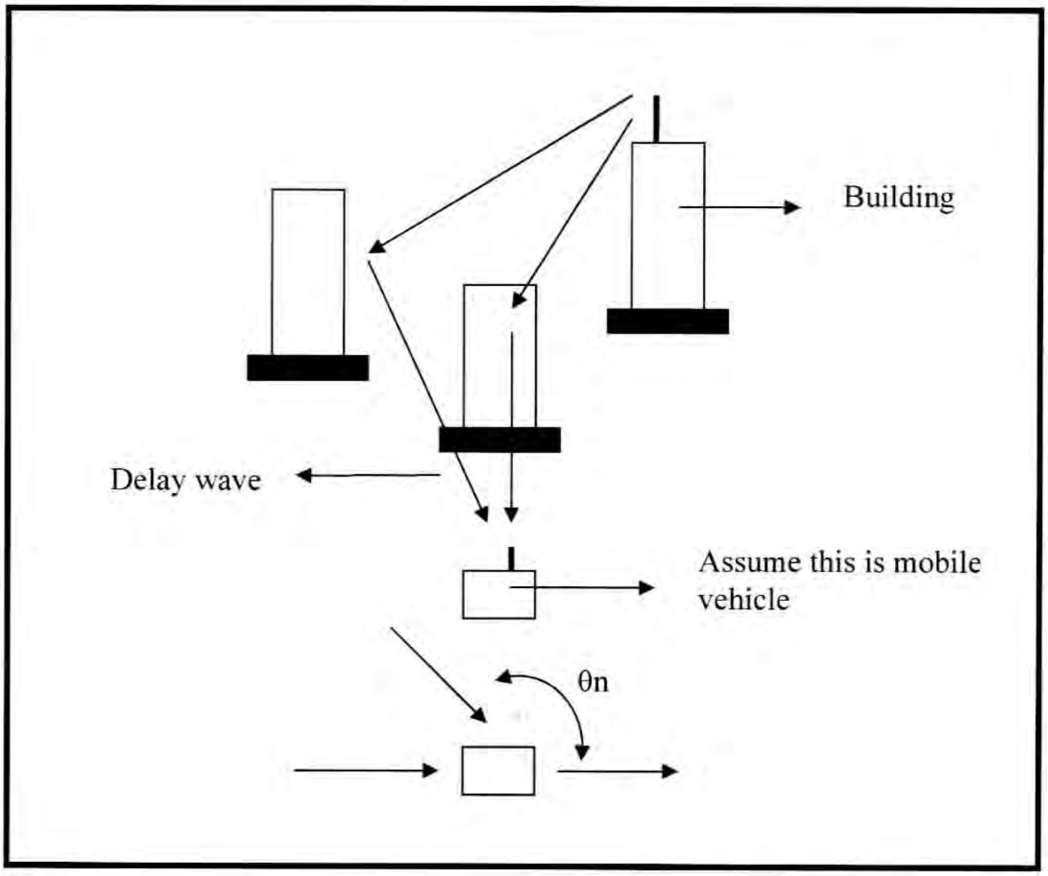

Figure 2.3: Principle of delay wave in Rayleigh fading.

The delay wave with incident angle θn is represented by

$$rn\,(t) = \mathrm{Re}\left[en\,(t)\exp j(\,2\pi fc\,t)\right] \qquad (2.1)$$

which corresponds to Figure 2.3, when a continuous wave of single frequency fc(Hz) is transmitted from the building. Re() indicates the real part of the complex number that gives the complex envelope of the incoming wave from the direction of the number n. Moreover, j is a complex number. en(t) is given in equation 2.2 by using the propagation path length of the incoming waves from the base station Ln (m), the speed of mobile station, v(m/s), and the wavelength, λ(m).

$$e_n\,(t) = R_n\,(t)\exp\left\{-\frac{2\pi(L_n vt\cos\theta_n)}{\lambda} + \phi_n\right\} \qquad (2.2)$$

$$= x_n\,(t) + jy_n\,(t)$$

where R_n and ϕ_n are the envelope and phase of the nth incoming wave. x_n (t) and y_n (t) are the in-phase and quadrature phase factors of e_n (t), respectively. The incoming nth wave shifts the carrier frequency to be v cos θ_n / λ (Hz) which is caused by the Doppler effect (Hz). This is called the Doppler shift in land mobile communication. When the incoming wave number is made to be N, the received wave, r (t) at the mobile station is synthesized from the incoming wave.

$$r\,(t) = \sum_{n=1}^{N} r_n\,(t)$$

$$= \mathrm{Re}\,[(\sum_{n=1}^{N} e_n\,(t))\ \exp j(\,2\pi f_c\,t)\,] \qquad (2.3)$$

$$= \mathrm{Re}\,[(x(t) + jy\,(t))\,(\,\cos 2\pi f_c\,t + j\sin 2\pi fc\,\,t\,)]$$

$$= x\,(t)\cos 2\pi f_c\,t - y\,(t)\,j\sin 2\pi f_c\,t$$

$$x\,(t) = \sum_{n=1}^{N} x_n\,(t) \qquad (2.4)$$

$$y\,(t) = \sum_{n=1}^{N} y_n\,(t)$$

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and x (t) and y (t) are normalized random process, having an average value of 0 and dispersion of σ, when N is large enough. For the combination probability density, p (x,y), where x = x(t), y = y (t)

$$p\,(x,y) = \frac{1}{2\pi\sigma^2}\exp\left(\frac{x^2+y^2}{2\sigma^2}\right) \qquad (2.5)$$

In addition, it can be expressed as r (t) using the amplitude and phase of the received wave.

$$r\,(t) = R\,(t)\cos(\,2\pi fc\ t + \theta\,(t)\,) \qquad (2.6)$$

R (t) and θ (t) are given by

$$R\,(t) = R = \sqrt{(\,x^2 + y^2\,)} \qquad (2.7)$$

$$\theta\,(t) = \theta = \tan^{-1}[\,y / x]$$

By using transformation of variable, p(x,y) can be converted into p (R,θ)

$$p\,(R,\theta) = \frac{R}{2\pi\sigma^2}\exp\left(-\frac{R^2}{2\sigma^2}\right) \qquad (2.8)$$

By integrating p (R,θ) over θ from 0 to 2, the probability density function p (R)

$$p\,(R,\theta) = \frac{R}{\sigma^2}\exp\left(-\frac{R^2}{2\sigma^2}\right) \qquad (2.9)$$

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Moreover, the probability density function p (θ) can be obtained by integrating p (R, θ) over from 0 to ∞.

$$p(\theta) = \frac{1}{2\pi} \qquad (2.10)$$

From this equation, the envelope fluctuation follows Rayleigh distribution, and the phase fluctuation follows uniform distribution due to the fading in the propagation path. So here, the mobile station receives the radio wave as shown in Figure 2.3. The arrival angle of the incoming wave at the receiver is uniformly distributed while the wave number of the incoming waves is set to N. In this case, the complex fading fluctuation in an equivalent lowpass system is:

$$r(t) = x(t) + j * y(t)$$

$$= \left[\sqrt{\frac{2}{N_1+1}}\sum_{n=1}^{N_1}\sin\left(\frac{\pi n}{N_1}\right)\cos\left\{2\pi f_d \cos\left(\frac{2\pi n}{N_1}\right)t\right\} + \frac{1}{\sqrt{N_1+1}}\cos(2\pi f_d t)\right]$$

$$+ j\sqrt{\frac{2}{N_1}}\sum_{n=1}^{N_1}\sin\left(\frac{\pi n}{N_1}\right)\cos\left\{2\pi f_d \cos\left(\frac{2\pi n}{N_1}\right)t\right\} \qquad (2.11)$$

where N_2 is an odd number and N_1 is given by

$$N_1 = \frac{1}{2}\left(\frac{N}{2} - 1\right)$$

In this case, the following relations are satisfied:

$$E\left[x_I^2(t)\right] = E\left[y_Q^2(t)\right] = \frac{1}{2}$$

$$E\left[x_I(t) y_Q(t)\right] = 0 \qquad (2.12)$$