SUPERVISOR APPROVAL

"I / We admit that to have read this report and it has follow the scope and quality in Partial Fulfillment Of Requirements For The Degree Of Bachelor of Electronic Engineering (Electronic Computer)"

Signature :

Supervisor Name : En Redzuan Bin Abdul Manap

Date : 5/5/2006

AN INVESTIGATION AND MODELING OF MULTIPATH EFFECT IN COMMUNICATION TRANSMISSION CHANNEL USING MATLAB

SUSANA LIU

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Faculty of Electronic Engineering & Computer Engineering
Kolej Universiti Teknikal Kebangsaan Malaysia

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DECLARATION

This Final Year Project contains information pertaining of Mechanically Scanned Clock with LED display. This project comes under the subject BEKU4983 Project offered by Faculty of Electronic Engineering & Computer Engineering, KUTKM. This documentation report aims to provide the reader about the overall information techniques about this project.

I admired that this is an original my own work with the exception which I have referenced them to explained sources.

Signature :

Writer Name : Susana Liu

Date : May 2006

Special thanks to my parents, my lovely cousin, Rose and Nurul Azirah for their support to make this project become reality.

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I treat as valid this report is doing by myself except summary and quotation in every part that I had clear source.

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ABSTRACT

In wireless communication systems, the transmitted signal is distorted by various phenomena that are intrinsic to the structure and contents of the wireless channel. Among these, multipath fading is a dominant source of distortion in wireless communications. Fading refers to the fluctuations in amplitude, phases and multipath delays over very short travel distances or very short time durations. Such channels typically represent wireless channels that introduce errors in bursts. In order to provide error protection to the message stream transmitted over such channels, redundancy is introduced by means of channel coding schemes. In this project, an analytical model to evaluate the transmitted signal trough the wireless communication system and effects of multipath and fading on the performance of a communication system channel is simulated using MATLAB.

Differential Phase Shift Keying (DPSK) will be used as a modulation sheme in this proposed model. For modeling multipath and fading effect, Rayleigh distribution will be used.

ABSTRAK

Sistem perhunbungan tanpa wayar dipengaruhi oleh beberapa fenomena semasa penghantaran isyarat. Antaranya ialah, *multipath fading* yang paling bayak mempengaruhi isyarat tersebut. *Fading* merujuk kepada perubahan pada amplitut, fasa dan serakan perjalanan isyarat dengan jarak penghataran isyarat. *Channel* penghantar isyrat memperkenal *error in burst* untuk mengelakan terdapat *error* yg dihantar semasa penghantaran tersebut. Satu model telah digunakan untuk menghantar isyarat tersebut dalam MATLAB. Pemudaran yg dapat dijanakan dalam projek ini adalah pemudaran Rayleigh. Isyarat yang akan dihantar dilemahkan oleh isyarat pemudaran ini. Program terdiri daripada empat peringkat utama iaitu simulasi terhadap pemudaran, pelaksanaan teknik pengkodan saluran, penjanaan saluran pemudaran dan penilaian kebarangkalian ralat bg isyarat yang diterima. Program termasuklah simulasi terhadap sistem pemodulan DPSK. Taburan pemuradaran dan hingar dapat diperhatikan.

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LISTOF ABBREVIATION

FCC	- Federal Communication Commission
FDMA	- Frequency-Division Multiple Access
AMPS	- Advanced Mobile Phone System
NMT	Nordic Mobile Telephony
NTT	- Nippon Telephone And Telegraph
TDMA	- Time-Division Multiple Access
GSM	- Global System For Mobile Communications
GMSK	- Gaussian Minimum Shift Keying
DQPSK	- Quadrature Differential Phase Shift Keying
DS-CDMA	- Direct Sequence Code Division Multiple Access
WWW	- World-Wide-Web
IMT-2000	- International Mobile Telephone 2000
ITU	- International Telecommunications Union
UMTS	- Universal Mobile Telecommunications Service
WLAN	- Wireless Local Area Network
SOHO	- Small Office Home Office
Hz	- Hertz
ISM	- Industrial, Scientific And Medical
MAC	- Medium Access
DSSS	- Direct Sequence Spread Spectrum
FHSS	- Frequency Hopping Spread Spectrum
OFDM	- Orthogonal Frequency Division Multiplexing
DAB	- Digital Audio Broadcasting
DVB	Digital Video Broadcasting
WBS	- Wireless Broadband Systems

BPSK	- Binary Phase Shift Keying
ASK	- Amplitude Shift Keying
FSK	- Frequency Shift Keying
PSK	- Phase Shift Keying
QPSK	- Quadrate Phase Shift Keying

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CHAPTER 1

OBJECTIVE AND SCOPE OF WORK (INTRODUCTION

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 thesis, 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.

The interference caused by fading produces significant random variations of signal power –in the scale of 10s of dB over fractions of the wavelength- about a mean power predicted by the Path Loss and Shadowing models[1]. As a result, fading can be extremely destructive to the signal and hence, in order to achieve reliable communication, provisions must be considered to counter the effects of fading.

This thesis project is concerned with producing a reusable simulation component in MATLAB, based on a somewhat simplified model of fading. 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.

1.1 OBJECTIVE

- To gain knowledge of signal generation model
- To model ideal communication system and to model multipath effect
- To improvement the model in MATLAB
- To produce working code/program

1.2 WORK SCOPE

There are many types of communication systems and, one of the most important communications systems in this day is wireless communication system. Basically wireless communication transmission had 3 components; there is transceiver, medium to transmit and receiver. There are more about basic communication system illustrations in the next chapter background study.

This project work includes the investigation and modeling these three basic components in communication system. It is also involving data investigation and modeling multipath and fading effects in wireless communication system of, in which all simulation is done by MATLAB.

MATLAB system is used to model the transmission channel and evaluation, such modeling an ideal transmission system, then generate the signal and noise, the transmission channel and etc.

1.3 METHODOLOGY

Project proposal gain the basic idea of the project, the problem and the objectives of the project in the real time application of communication system. Next a literature review stage is required, where information on wireless communication and multipath effect and also fading (internet, wireless communication books, IEEE journal and others source that related to this matter) is studied. Also knowledge on MATLAB is to be studied to implemented the fading occur in wireless communication system.

Development of deal communication system and subsequently modeling the system without any distortion and noise is done in MATLAB. The system is then compared to the system where its signal has been affected by noise and fading.

This fading effect is modeled by the simulator. Performances analysis where the signal has been added with multipath and fading are analyzed.

CHAPTER 2

BACKGROUND STUDY

2.1 BACKGROUND OF WIRELESS SYSTEMS

Research on aspects of wireless communications related to consumer applications has been active for at least the last thirty years. In 1970, the Federal Communication Commission, (FCC) made available a 75 MHz band in the 806-881 MHz range for mobile telephony[1]. This relatively large capacity system paved the way for significant innovations in cellular networks, personal communications services and more recently for data services on wireless networks. The evolution is often captured in terms of first (1G), second (2G) and third (3G) generation systems. The 1G systems encompass the analog cellular systems that are based on frequency-division multiple access (FDMA). These systems were standardized in the United States as Advanced Mobile Phone System (AMPS), as Nordic Mobile Telephony (NMT) in the European Nordic countries and the Nippon Telephone and Telegraph (NTT) system in Japan[1]. The AMPS system supports 832 channels at 30 KHz carrier spacing. The 2G systems that evolved from the mid to late eighties focussed on digital modulation techniques and time-division multiple access (TDMA) schemes. The Global System for Mobile Communications (GSM) European standard was the first 2G implementation. It was designed to support slow rate date services in the 2.4-9.6 Kbps range. It uses 200 KHz carrier spacing and Gaussian minimum shift keying (GMSK) modulation that can support bit rates of 270. 8 Kbps. The Interim Standard 54 (IS-54 / IS-136) in North America is the counterpart to GSM. It is however reversing compatible to AMPS while using TDMA with 30 KHz carrier spacing and π /4 phase-shifted quadrature differential phase shift keying π /4 DQPSK and bit rates of 48.6 Kbps [1][2]. These systems provided a much-needed increase in the capacity. In 1993 a higher capacity 2G system based on direct sequence code division multiple access (DS-CDMA) technology proposed by Qualcomm Inc. was implemented in the United States IS-95 standard. These systems have been shown to provide around an order of magnitude increase in capacity over AMPS technology [1], [2].

The advent of the world-wide-web (WWW) and commercialization of the Internet during the mid nineties set the tone for expected functionality of the third generation systems. Wireless communication no longer meant mobile plain voice telephony service. Wireless services are expected to include voice mail, e-mail, instant messaging, and multimedia messaging, web and intranet access. These services are to be supported on digital devices such as cellular phone, personal digital asistance PDA, the personal computer and its peripherals. Spread spectrum technology on which CDMA is based was considered as the most viable means of achieving the higher data rates required for multimedia wireless transmission. However, 3G standards based on the GSM TDMA model are also being considered. The 3G standards have been addressed in the International Mobile Telephone 2000 (IMT-2000) specifications put forth by the International Telecommunications Union (ITU). These systems were targeted to operate globally in the 2 GHz frequency range. The evolution of IS-54 and GSM to 3G is specified as wideband CDMA (WCDMA) or Universal Mobile Telecommunications Service (UMTS) systems. The IS-95 extension to CDMA is referred to as CDMA2000. These two systems are expected to be co-existing platforms in the current decade. The 3G systems use the 1.8-2.2 GHz frequency band and maximum bandwidth is 140 MHz [3].

Most, if not all of the aforementioned standards activities have focused on the support of enhanced mobile telephony services. In the last five years, the demand for fixed wireless systems has arisen, particularly in the context of setting up ad-hoc networks for various consumer and business related applications. The concept of the wireless local area network (WLAN) is a case in point. The application of WLANs may be found in campus offices, small office home office (SOHO), hospitals, residences, warehouses, manufacturing facilities, parking lots, building-to- building complexes and limited outdoor regions. In the last two years, major computer and telecommunication systems providers have developed cost effective wireless terminal cards and access points for deploying WLANs. It is instigated in large part by the availability of the Industrial, Scientific and Medical (ISM) frequency bands in the 902-928, 2400-2483.5 MHz and 5.725-5.825 GHz ranges [4]. The FCC allows operation of low-power spread spectrum (SS) devices in these frequency bands. The IEEE 802.11 working group focuses on the standardization of SS devices for WLANs. The first wireless LAN standard was issued by IEEE in 1997, based on international consensus, except Europe. This was the IEEE 802.11 wireless LAN standard. The 802.11 specifies the physical and medium access (MAC) layers for operation of WLANs and addresses the direct sequence spread spectrum (DSSS) and frequency hopping spread spectrum (FHSS) access methods for the radio medium. The 802.11 supports both asynchronous and synchronous data transfer mode. The asynchronous data transfer is applied to non-time sensitive applications such as e-mail and file transfers. The synchronous mode supports time bounded applications like video and pocketsize voice [5]. The IEEE 802.11 supports 3 different MAC layers: 2.4 GHz radio FHSS, 2.4 GHz DSSS and infrared (IR) with 1 and 2 Mbps data rate. The IEEE 802.11b can support data rate of 5.5-11 Mbps in the same MAC layer with 20 MHz bandwidth and 3 cell frequency reuse pattern. The IEEE 802.11a in 5 GHz band, supports 6-54 Mbps data rate with maximum 200 MHz band, 48 subcarriers, orthogonal frequency division multiplexing (OFDM) and 4 cell reuse pattern. The IEEE 802.11g standard for WLANs, which will extend the data rate of the IEEE 802.11b to 54 Mbps from current level of 11 Mbps using same 2.4 GHz physical layer, has been approved by the IEEE working group.

The OFDMmodulation scheme is used for European digital audio broadcasting (DAB) and digital video broadcasting (DVB) standard and it is also a strong candidate modulation scheme for digital television broadcasting in North America [2], [6] and next generation wireless LAN, IEEE 802.11g, and wireless broadband systems (WBS). This scheme has attracted much interest in the last few years because of its robustness to multipath fading and it intrinsic characteristics of multicarrier modulation for supporting maximum data rate. The complementary open standard referred to as Bluetooth has also evolved for supporting wireless communication by various kinds of digital devices that are small in size and of relatively low cost. The Bluetooth wireless specification includes both link and application layer definitions for product developers and is aimed at supporting data, voice and content centric applications. These systems also operate in the unlicensed; 2.4 GHz ISM band to support worldwide compatibility. Bluetooth uses a spread spectrum, frequency hopping, full duplex signal at up to 1600 hops/sec [2][7][8]. There are 78 frequency hopping channels with 1 MHz bandwidth to give a high degree of interference immunity. A maximum of 7 connections of devices can be established and maintained. There are transmitter power limitation regulations to support small frequency reuse pattern. The maximum output power is specified at 100 mW for class 1, 2.5 mW for class 2 and 1 mW for class 3 devices. Bluetooth supports up to 1 Ms/s symbol rate with Gaussian frequency shift keying (GFSK) modulation scheme [9].

2.2 SYSTEM AND CHANNEL MODEL

A communication system using binary phase shift keying (BPSK) modulation is considered. The mobile user's data bit stream b_n is modeled as a sequence of mutually independent binary random variables, each with probability 1/2 of being 1. The resulting baseband model of the transmitted waveform for the BPSK signal with rate R is given by [10]

$$R = 1/T_{n(t)} = \sqrt{\frac{2}{T}} \sum_{n=-\infty}^{\infty} b_n l_n \, {}_{PT}(t - nt) \qquad (1)$$

Where ${}_{PT}(t)$ unit amplitude is is pulse in the interval $[0,T]$ and l_n is the correction factor due to closed-loop power control. The transmitted signal is corrupted by multipath fading and additive white Gaussian noise. By using a narrowband system model, the multipath fading is accurately modeled as a frequency nonselective time-varying multiplicative distortion with some phase shift. At the receiver, phase can be assumed that it has perfectly estimated. Thus, with coherent reception, the effect from fading is only due to the multiplicative effect. The input to the receiver is then given by [11]

$$r(t) = a(t)s(t) + n(t) \tag{2}$$

Where $a(t)$ a Rayleigh is random process and $n(t)$ is additive white Gaussian noise with two-sided spectral density $N_0/2$. It is assumed that the fading stays constant over the entire bit duration, hence $a(t) = a_n$, for. $(n-1)T \le t < nT$. After the received signal is passed through an appropriately normalized matched filter, the output of the receiver is [12]

$$Zn = a_n l_n b_n + \eta_n \tag{3}$$

Where η_n is the matched filter output due to thermal noise with variance $N_0/2$. If Zn is greater than 0 the receiver demodulates bit to be 1, otherwise, the bit is demodulated to be -1.

2.3 DIGITAL MODULATION AND DEMODULATION

The method of demodulation is an important factor in determining the selection of a modulation scheme. There are two types of demodulation which are distinguished by the need to provide knowledge of the phase of the carrier. Demodulation schemes requiring the carrier phase are termed **coherent**. Those that do not need the phase are termed **incoherent**. Incoherent demodulation can be applied to amplitude shift keying (ASK) and wide-band frequency shift keying (FSK). It describes demodulation schemes that are sensitive only to the power in the signal. With ASK, the power is either present, or it is not. With wide-band FSK, the power is either present at one frequency, or the other. Incoherent modulation is inexpensive but has poorer performance. Coherent demodulation requires more complex circuitry, but has better performance.[13]

In ASK incoherent demodulation, the signal is passed to an **envelope detector**. This a device that outputs the "outline" of the signal. A decision is made as to whether the signal is present or not. Envelope detection is the simplest and cheapest method of demodulation. In optical communications, phase modulation is technically very difficult, and ASK is the only option. In the electrical and microwave context, however, it is considered crude. In addition, systems where the signal amplitude may vary unpredictably, such as microwave links, are not suitable for ASK modulation.

Incoherent demodulation can also be used for wide-band FSK. Here the signals are passed to two circuits, each sensitive to one of the two carrier frequencies. Circuits whose output depends on the frequency of the input are called **discriminators** or **filters**. The outputs of the two discriminators are interrogated to determine the signal. Incoherent FSK demodulation is simple and cheap, but very wasteful of bandwidth. The signal must be wide-band FSK to ensure the two signals $f_1(t)$ and $f_2(t)$ are distinguished. It is used in circumstances where bandwidth is not the primary constraint.

With coherent demodulation systems, the incoming signal is compared with a replica of the carrier wave. This is obviously necessary with phase shift keying (PSK) signals, because here the power in the signal is constant. With binary PSK the comparison is performed by multiplying the incoming signal with a replica of the carrier. If the output of this process is, we have that: [14]

$$\begin{aligned} h(t) &= f(t)\sin(2\pi f_c t)\sin(2\pi f_c t) \\ &= f(t)[1-\cos(4\pi f_c t)]/2 \qquad (4) \end{aligned}$$

i.e. the original signal plus a term a twice the carrier frequency. By removing, or filtering out the harmonic term, the output of the demodulator is the modulation $f(t)$. With quadrate phase shift keying QPSK, the processing is more complicated, and two separate demodulators are required. The demodulator complexity increases rapidly for M-ary PSK; for this reason it is rarely used.

The difficulty with coherent detection is the need to keep the phase of the replica signal, termed **local oscillator**, "locked" to the carrier. This is not easy to do. Oscillators are sensitive to (among other things) temperature, and a "free-running" oscillator will gradually drift in frequency and phase. Suppose there is some phase error $\Delta\phi$ present in the local oscillator signal. After filtering, the output of a BPSK demodulator will be:

$$h(t) = f(t)[\Delta\phi]/2 \tag{5}$$

According to the value of $\Delta\phi$, $h(t)$ may take the value -1 to 1 with every value in-between. Clearly, the consequence for the correct interpretation of the demodulated signal is catastrophic.

2.3.1. Differential Phase-Shift Keying

There are two methods to prevent such an occurrence. In one, a pilot carrier signal is sent in addition to the modulated carrier. This pilot carrier is used to synchronise the local oscillator phase. The alternative is to employ another form of modulation, **differential phase-shift-keying (DSPK)**. DPSK is actually a simple form of coding. The modulating signal is not the binary code itself, but a code that records *changes* in the binary code. This way, the demodulator only needs to determine changes in the incoming signal phase. Because the drifts associated with local oscillators occur slowly, this is not difficult to arrange. (The simple multiplier used above is still inadequate, but the alternatives are no more complicated.) [15]

The PSK signal is converted to a DPSK signal with two rules:

1. a 1 in the PSK signal is denoted by no change in the DPSK
2. a 0 in the PSK signal is denoted by a change in the DPSK signal

The sequence is initialised with a leading 1. An example of the pattern is thus:

```
PSK    0 1 0 0 1 1 0 1
DPSK 1 0 0 1 0 0 0 1 1
```

2.4 MULTIPATH AND FADING

MULTIPATH is simply a term used to describe the multiple paths a radio wave may follow between transmitter and receiver. Such propagation paths include the ground wave, ionospheric refraction, reradiation by the ionospheric layers, reflection from the earth's surface or from more than one ionospheric layer, and so on. Figure 2-1 shows a few of the paths that a signal can travel between two sites in a typical circuit.