COPYRIGHT © 2011 IJCIT, ISSN 2078-5828 (PRINT), ISSN 2218-5224 (ONLINE), VOLUME 01, ISSUE 02, MANUSCRIPT CODE: 110125

Performance Comparison of AWGN, Flat Fading and Frequency Selective Fading Channel for Wireless Communication System using 4QPSK

Md. Sipon Miah, M. Mahbubur Rahman, T. K Godder, Bikash Chandra Singh *and* M. Tania Parvin

Abstract— In this thesis paper, first build up a wireless communication simulator including Gray coding, modulation, different channel models (AWGN, flat fading and frequency selective fading channels), channel estimation, adaptive equalization, and demodulation. Next, test the effect of different channel models to the data and image in receiver with constellation and BER (bit error rate) plots under 4QPSK modulation which is a high data rate then QPSK. For Image data source, we also compare the received image quality to original image in different channels. At last, give detail results and analyses of the performance improvement with channel estimation and adaptive equalization in slow Rayleigh fading channel. For frequency selective fading channel, use linear equalization with both LMS (least mean squares) and RLS (Recursive Least Squares) algorithms to compare the different improvements. We will see that in AWGN channel, the image is slight degraded by random noise; in flat fading channel, the image is serious degraded by random noise and block noise; in frequency selective fading channel, the image is very serious degraded by random noise, block noise, and ISI.

Index Terms —Slow fading, flat fading, frequency selective fading, channel estimation, LMS, RLS, 4QPSK, ISI.

1 INTRODUCTION

MOBILE communications and wireless networks 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 well known that the wireless multi-path channel causes an arbitrary time dispersion, attenuation, and phase shift, known 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. There are many diversity techniques to address fading issue, such as OFDM, MIMO, RAKE receiver and etc. However, it may be still necessary to remove the amplitude and phase shift caused by the channel if we want to apply linear modulation schemes, such as the ones used in WiMAX. The function of channel estimation is to form an estimate of the amplitude and phase shift caused by the wireless channel from the available pilot information. Channel estimation methods may be divided into two classes: pilot based estimation and blind estimation. In our project, we will focus on pilot-based channel estimation with training data. The equalization removes the effect of the wireless channel and allows subsequent symbol demodulation. An adaptive equalizer is a time-varying filter which must constantly be retuned. A number of different algorithms can be employed for these modules. In our project, we use LMS (least mean squares) and RLS (Recursive Least Squares). Digital communication systems operating on time varying dispersive channels often employ a signaling format in which customer data are organized in blocks preceded by a known training sequence. The training sequence at the beginning of each block is used to estimate channel or train an adaptive equalizer. Depending on the rate at which the channel changes with time, there may or may not be a need to further track the channel variations during the customer data sequence. Fig.1 shows the flow chart of our MATLAB simulation which is used in this project.

- *M. S Miah, Lecturer, Department of Information & Communication Engineering,Islamic University, Kushtia-7003, Bangladesh. E-mail: mdsiponmiah@gmail.com.*
- *Dr. M. M Rahman, Professor, Department of Information & Communication Engineering,Islamic University, Kushtia-7003, Bangladesh. E-mail: drmahbub_07@yahoo.com*
- *T. K Godder, Associate Professor, Department of Information & Communication Engineering,Islamic University, Kushtia-7003, Bangladesh. E-mail: tkict@yahoo.com:*
- *B. C Singh, Lecturer, Department of Information & Communication Engineering,Islamic University, Kushtia-7003, Bangladesh. E-mail: bikashsingh18@yahoo.com*
- *M. Tania Parvin, M. Sc Student, Department of Information & Communication Engineering, Islamic University, Kushtia-7003, Bangladesh.*

2 WIRELESS MOBILE COMMUNICATION SYSTEMS

In any communication system, there must be an information source (transmitter), a destination (receiver) and a medium to transmit information between the transmitter and the receive. The block diagram of a basic communication system is given in Fig-1. Message source originates message such as human voice, a television picture a teletype message or data. The message can be electrical and non-electrical. If it is not electrical, the source transducer will convert it into electrical signal. The transmitter may be consists of analog to digital converter, data compressor, source encoder, channel encoder a modulator or any other complicated subsystems.

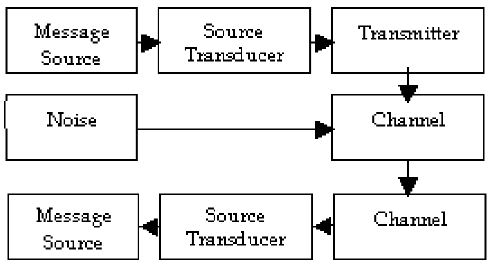


Fig. 1 Block diagram of basic communication System

The receiver may be consists of demodulator, channel and source decoders data expender, digital to analog converter or others. Receiver transducer converts the electrical signal to its original form- the message. Message destination is the actual unit to which the message it sent. The channel is the information transmission medium. This medium can be of different types such as wire, a waveguide, an optical fiber or a wireless link. As the channel act as a filter, during the transmission of the signal (message) through the channel, the signal can be distorted due to the attenuation and phase shift suffered by different frequency component of the signal. Noise will also be added with the transmitted signal during the transmission of the signal through the channel. This noise is of random type and unpredictable. Interference from other users; faulty electrical equipments; automobile ignition radiation; fluorescent light, lightning, solar and intergalactic radiation; thermal motion of electrons in conductors; random emission, diffusion and recombination of charged carriers in electronics devices are some sources of channel noise. In case of wireless communication system, the channel will be a radio link, which means free space propagation is used in this case. There will be no physical connection between the source and the destination. In case of wireless communication two cases can arises as follows.

1. The source and the destination both are static, i.e., they are fixed in position and not movable.
2. The source and the destination are not static, i.e., either source and destination or both are movable.

The second case where the source and the destination can be moveable and radio link is used for communication, is termed as wireless mobile communication.
The wireless mobile communication can be of two types:

1. Non-Cellular (i.e., signal cell) Mobile Communication.
2. Cellular Mobile Communication.

2.1 Non-cellular wireless mobile communication

In non-cellular (single cell) mobile communication system, the coverage area is not divided into small cells as in cellular system. The coverage area can vary from a small area to a wide one. For small coverage area, the transmitted power, infrastructure cost and complexity are low, TV remote control, garage door opener and cordless phone are few examples of non-cellular wireless communication serving a small coverage area, for wide area coverage, high power transmitter placed at a high elevation is used, a single high power transmitter would be used for a large city. The non-cellular mobile communication system is also being used by small taxi-companies, utility companies, fire, police, medical and emergency personnel and national operators of large vehicle fleets based on land and sea. Wireless local area networks (WLANs) and the evolving Bluetooth technology are also examples of non-cellular wireless communication.

2.2 Cellular wireless mobile communication

In the early mobile radio systems, the objective was to achieve a large coverage area by using a single, high powered transmitter with an antenna mounted on a tall tower, as frequency reuse was not possible, the problem of this system was that the user capacity was very low. For example, the Bell Mobile system in New York city in 1970s could only support a maximum if twelve simultaneous calls over a thousand square miles. Thus the need of higher capacity with limited radio channel brought into the cellular concept. Modern cellular concept began to appear in Bell system proposals during the late 1940s. In cellular case, a coverage area is divided into a large number of small cells, each equipped with a low-power transmitter and each transmitter provides services for a small portion of the total geographic service area. The same frequencies could be reused in different cells. The most important properties of cellular architecture are as below.

- Low power transmitters per cell
- Small coverage area per cell
- Frequency reuse
- Cell splitting to increase capacity

2.3 Cellular Telephone System

A cellular telephone system provides a wireless connection to the PSTN for any user location within the radio range of the system. Cellular systems accommodate a large number of users over a large geographic area, within a limited frequency spectrum. Cellular radio systems provide high quality service that is often comparable to that of the landline telephone systems. High capacity is achieved by limiting the coverage of each base station transmitter to a small geographic area called a cell so that the same radio channels may be reused by another base station located some distance away. A sophisticated switching technique called a handoff enables a call to proceed uninterrupted when the user moves from one cell to another.

A basic cellular system which consists of mobile stations, base stations and mobile switching centers (MSC), the mobile switching center is sometimes called a mobile telephone switching office (MTSO), since it is responsible for connecting all mobiles to the PSTN in a cellular system. Each mobile communicates via radio with one of the base stations and may be handed-off to any number of base stations throughout the duration of a call. The mobile station contains a transceiver, an antenna, and control circuitry, and may be mounted in a vehicle or used as a portable hand-held unit. The base stations consist of several transmitters and receivers which simultaneously handle full duplex communications and generally have towers which support several transmitting and receiving antennas. The base station serves as a bridge between all mobile users in the cell and connects the simultaneous mobile calls via telephone lines or microwave links to the MSC. The MSC coordinates the activities of all of the base stations and connects the entire cellular system to the PSTN.

A typical MSC handles 100,000 cellular subscribers and 5,000 simultaneous conversations at a time, and accommodates all billing and system maintenance functions, as well. In large cities, several MSCs are used by a single carrier. Communication between the base station and the mobiles is defined by a standard common air interface (CAI) that specifies four different channels. The channels used for voice transmission from the base station to mobiles are called forward voice channels (FVC), and the channels used for voice transmission from mobiles to the base station are called reverse voice channels (RVC).The two channels responsible for initiating mobile calls are the forward control channels (FCC) and reverse control channels (RCC).

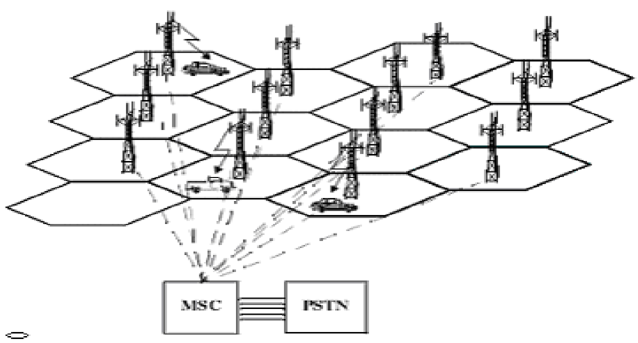


Fig. 2 A Celluar System

Control channels are often called setup channels because they are only involved in setting up a call and moving it to an unused voice channel. Control channels transmitted receive data messages that carry call initiation and service requests, and are monitored by mobiles when they do not have a call in progress. Forward control channels also serve as beacons which continually broadcast all of the traffic requests for all mobiles in the system. Supervisory and data messages are sent in a number of ways to facilitate automatic channel changes and handoff instructions for the mobiles before and during a call.

Cellular systems rely on the frequency reuse concept, which requires that the forward control channels (FCCs) in neighboring cells be different. By defining a relatively small number of FCCs as part of the common air interface, cellular phones can be manufactured by many companies which can rapidly scan all of the possible FCCs to determine the strongest channel at any time. Once finding the strongest signal, the cellular phone receiver stays “camped” to the particular FCC. By broadcasting the same setup data on all FCCs at the same time, the MSC is able to signal all subscribers within the cellular system and can be certain that any mobile will be signaled when it receives a call via the PSTN.

2.4 Problems in Cellular Mobile Communications

In a cellular system interference is the major limiting factor in increasing capacity. Some of the interference sources are for example. Other base station transmitting in the same frequency band, another mobile user in the same cell, a call in progress in a neighboring cell, impairments caused by the propagation of radio waves, Etc. as a result. Different types of system interference are yielded in the network. Among these interferences the most important are the following.

Co-channel interference (CCI this type of interference is caused by the interference between co-channel cells (cells with the same frequency channel) due to the frequency refuse. To reduce CCI, co-channel cells must be separated by a minimum distance to provide sufficient isolation due to propagation distance.

Adjacent channel interference (ACI) This other type of interference results when two frequency channels are adjacent in the frequency spectrum and one of them is leaking into the pass band causing interfering into the adjacent channel.

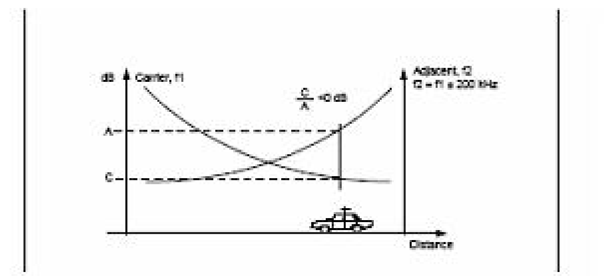


Fig. 3 Adjacent Channel

ACI is mainly aggravated by imperfect receiver filters. This problem can be minimized with a careful filtering and channel assignments (assigning channels to a cell which is not adjacent in frequency).

Inter-symbol interference (ISI) When the signal travls through a channel, objects in ansmission path can create multiple echoes of the signal. hoes occur at the receiver and overlap in successive e slots. This is known as inter-symbol interference equalizers at the receiver can be used to compensate the effect of ISI created by multi-path within time dispersive channels.

Fading one consequence of transmitting a signal through a time –varying multi-path channel is to confront at the receiver with a signal fading (amplitude variations in the received signal). Hence not only the propagation delays but also the random impulse responses of the channel will provoke some attenuation and time spread of the signal transmitted.

Thermal noise finally, the additive thermal noise is a factor that always corrupts a transmitted signal through a communication channel. Generally this thermal noise is assumed to be an additive white Gaussian noise (AWGN).

3 CHANNEL FADING TECHNIQUES

The physical medium between the transmitter and reeiver is known as channel. This channel results in random delay (random phase shift) with total a factor. Channels may be three types:

Type	Description	Examples
Simplex	One way only	FM radio, television
Half duplex	Two way, only one at a time	Poice Radio
Full duplex	Two way, both at the same time	Mobile systems

3.1 Additive White Gaussain Noise

Zero-mean white Gaussian Noise (WGN) has the same power spectral density AWGN(f) for all frequencies. The adjective 'white' is used in the sense that white

$$Ra_{WGN}(\tau)\int_{-\infty}^{+\infty} gwn(T).gwn(t+\tau)dt = F^{-1}\{G_{WGN}(f)\} = \frac{N_0}{2}\delta(\tau)$$

light contains equal amounts of all frequencies within the visible band of electromagnetic radiation. The autocorrelation function of WGN is given by the inverse Fourier transform of the noise power spectral density GWGN(f):
The autocorrelation function RaWGN (t) is zero for t≠0. This means that any two different samples of WGN, no matter how close together in time they are taken, are uncorrelated. The noise signal WGN (t) is totally decorrelated from its time shifted version for any t≠0.

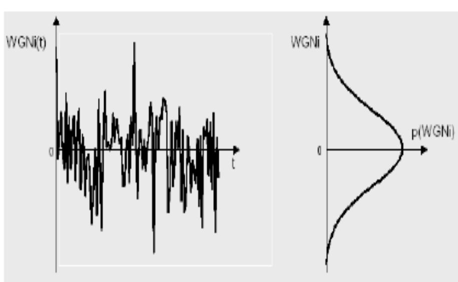


Fig. 4 Signal with AWGN Noise

The amplitude of 'integrated' (bandwidth) WGN has a Gaussian probability density distribution P(WGNi):

Noise exists in all communications systems operating over an analog physical channel, such as radio. The main sources are thermal background noise, electrical noise in the receiver amplifiers, & inter-cellular interference. In addition, this noise can also be generated internally to the communications system as a result of Inter-Symbol Interference, Inter-Carrier Interference & Inter-Modulation Distortion. These sources of noise decrease the Signal to Noise Ratio (SNR) & thus limiting the spectral efficiency of the system. Noise is the main detrimental effect in most radio communication systems.

Most types of noise present in radio communication systems can be modelled accurately using Additive White Gaussian Noise (AWGN). This noise has a uniform spectral density & a Gaussian distribution in amplitude. Thermal & electrical noise from amplification, primarily have white Gaussian noise properties, allowing them to be modeled accurately with AWGN. Also most other noise sources have AWGN properties due to the transmission being OFDM. OFDM signals have a flat spectral density & a Gaussian amplitude distribution provided that the number of carriers is large, because of this the inter-cellular interference from other OFDM systems have AWGN properties. For the same reason ICI, ISI, & IMD also have AWGN properties for OFDM signals.

$$P(WGNi) = \frac{1}{\sigma\sqrt{2\pi}} e^{\left[-\frac{1}{2}\left(\frac{x}{\sigma}\right)^2\right]}$$

3.2 Rayleigh Fading Channels

When information is transmitted in an environment with obstacles (Non Line-of-sight - NLOS), more than one transmission paths will appear as result of the reflection(s). The receiver will then have to process a signal which is a superposition of several different transmission paths. If there exists a large number of transmission paths may be modeled as statistically independent; the central limit theorem will give the channel the statistical characteristics of a Rayleigh Distribution [36]. (Fig 5)

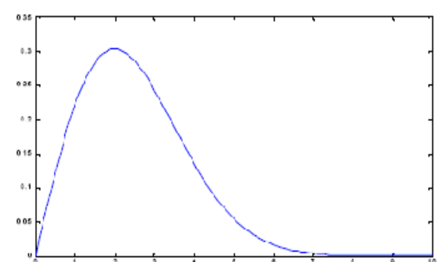


Fig. 5 Rayleigh distribution

3.3 Multipath Fading

In a radio propagation channel, there are two types of fading; large scale and small scale. Large signal fading is the attenuation caused by the path loss over large distances and shadowing effects and is well represented by log-normal models. Small scale fading occurs in the range of the signal wavelength and is much more random as compared to large scale fading. Small scale fading is mainly a result of multiple multipath components undergoing constructive/destructive interference at any point. In the common case where there is no line of sight (LOS) component between the transmitter and the receiver, the received power follows a Rayleigh distribution and can be seen to have a Rayleigh fading envelope.

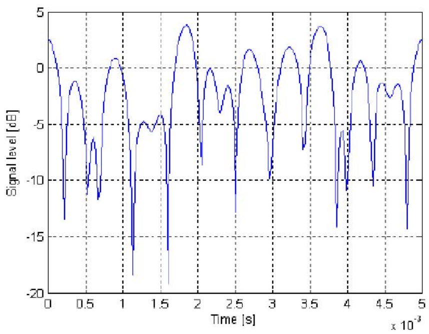


Fig. 6 Typical Rayleigh fading envelope at 1 kHz Doppler spread (0.423ms coherence time)

3.4 Large Scale Fading

The large scale fading refers to the degradation of the signal strength due to the path loss as a function of the distance between the transmitter and the receiver and shadowing effects caused by the surrounding environmental clutter. The path loss is the gradual loss of received signal power with the distance from the transmitter. Shadowing describes the random effects which occur at different locations which have the same transmitter receiver separation, but different surroundings on the propagation path.

3.5 Shadowing

From the above equation only gives an ensemble average value, which does not take into account the variability in the propagation path between the transmitter and the receiver. Empirical data measurements have shown that the received signal power at a particular distance *d* is distributed log-normally (normally in dB) about the distance-dependent average received signal power. When the log-normal shadowing is included, the large scale fading at a distance *d*, can be expressed as:

Where *X* represents a normally distributed random variable with zero mean and variance σ^2. The variance of the log-normal shadowing is calculated based on measurements that are taken over a wide range of locations that have the same transmitter receiver separation but with different environmental clutter. Apart from this simple model of the above equation, there exist various empirical models that take into account the *terrain profile* of a particular area in the propagation predictions (such as Okumura model [11] and Hata model [12]).

3.6 Small Scale Fading

Small scale fading itself can be subdivided into two other types. One is based on the multipath delay spread and the other on the Doppler shift. Depending on the relative length of the multipath delay spread (σ_τ) with respect to the OFDM symbol length we can have either Flat Fading or Frequency Selective Fading. Similarly, the relative magnitude of the channel coherence time (as a result of the Doppler shift) with respect to the OFDM symbol duration determines whether the signal undergoes Fast Fading or Slow Fading [10].

3.7 Flat Fading

Flat fading is the name given to the case when the channel coherence bandwidth is larger than the signal bandwidth and hence all frequencies of the transmitted signal experience the same channel condition; i.e., over the signal bandwidth, the channel frequency response is essentially flat; and hence the name Flat Fading. In the time domain, this corresponds to having an expected σ_τ smaller than the signal symbol period.

3.8 Frequency Selective Fading

$$P_r(d) = P_r(d_0)\left(\frac{d_0}{d}\right)^{\gamma} 10^{X}$$

On the other hand, if the channel bandwidth is narrower than the signal bandwidth, different frequency bands of the signal are affected differently. The time domain analogue is that the channel σ_τ is larger than the signal symbol period.

3.9 Fast Fading

In a fast fading channel, the rate of change of the channel is higher than the signal symbol period and hence the channel changes over one period. In other words, the channel coherence time, T_c, is smaller than the symbol period. T_c is related to the Doppler spread, fm, as

$$T_c = 0.423 / f_m$$

From this relation it is clear that a high Doppler spread results in a smaller channel coherence time. The coherence time of 0.423ms corresponding to a f_m of 1kHz is clear.

3.10 Slow Fading

As the name suggests, in a slow fading channel, the channel coherence time is larger than the symbol period and hence the channel remains approximately static over a symbol or multiple symbols. From the above equation it is clear that slow fading is usually expected with low Doppler spread values; i.e. with slower moving obstacles and receiver/transmitter. Multipath delay spread based and Doppler spread based fades are completely independent of each other and hence is quite possible to have a flat, fast fading channel or a flat, slow fading channel; and so on.

4 RESULT AND DISCUSSION

I discuss my simulation result by two steps. First I analyze the performance comparison by different parameter setting in each channel. Then I analyze the performance by comparing three different channels under the same parameters setting. All the simulations are based on QPSK modulation with gray code.

4.1 For AWGN channel

A. BER of simulation vs theoretical

As shown in figure 7, The BER performance of imulation result is closely identical to theoretical BER.

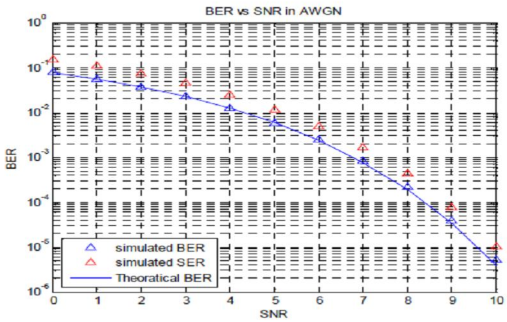


Fig. 7 BER of simulation vs theoretical

B. Image quality of received vs original

In figure 8, the received image is plot at SNR = 5dB, we see there are some random noises in the image. From simulation result, the received image quality is almost the same as original at SNR = 10Db.

F

Fig. 8(a) Original

Fig. 8(a) Image quality of received

C. BER of image vs random data

The correlation between image pixels does not effect the BER in AWGN channel.

4.2 For Flat Fading Channel

A. BER of simulation vs theoretical

As shown in figure 9 the BER performance of simulation result is worse than theoretical BER. This is reasonable, since the theoretical BER is based on the assumption that we know exactly the phase information of modulated signal. However, due to the time-variant channel, we always have estimation error for phase information. We also find the BER performance is improved dramatically in low SNR, while not in high SNR. This is also reasonable, since in low SNR, white Gaussian noise dominate the BER error, which can be improved by enhancing SNR, while in high SNR, phase estimation error dominate the BER error, which can not be improved by simply enhancing SNR .

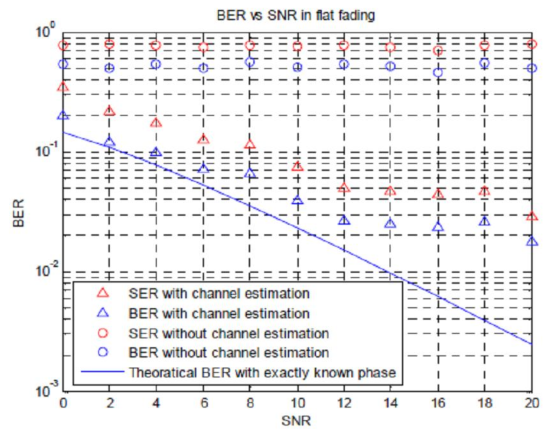


Fig. 9 BER of simulation vs theoretical

B. BER & constellation of training vs non-training

As shown in figure 11 and figure 12 the constellation is plot at SNR = 10dB, we see both the BER performance and constellation are greatly improved by channel phase estimation.

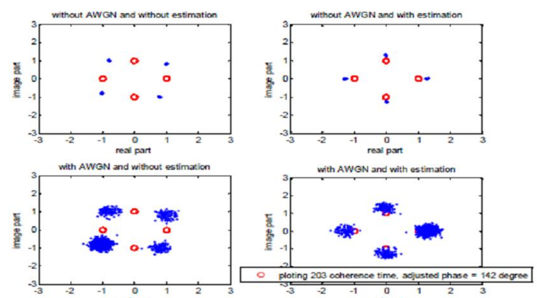
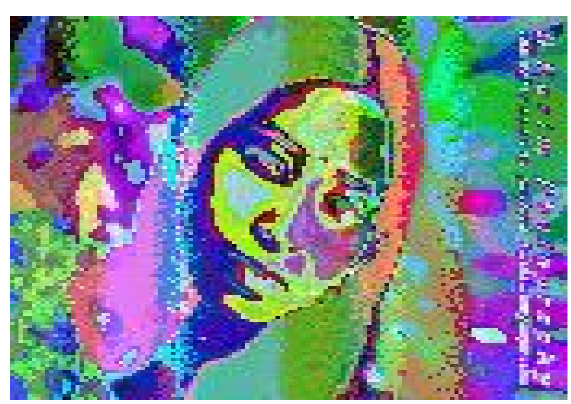


Fig. 11 BER & Constellation of training vs nontraining



(a)

(b)

Fig. 12(a) Without adjustment (b) With adjustment

C. Image quality of received vs adjusted

In figure 6, the received image is plot at SNR = 10dB, we see that other than some random noise, there is some block noise in the image. This is due to the phase estimation error in a coherence time.

D. BER of image vs random data

The correlation between image pixels does not affect the BER in flat fading channel.

4.3 For frequency selective fading channel

A. BER of simulation vs theoretical

As shown in figure 13, the BER performance of simulation result is worse than theoretical BER. The reason is same from above reason addressed in flat fading channel. Different from in flat fading channel, the BER performance is improved dramatically in low SNR, while even degraded in high SNR. This is also reasonable, since in high SNR, phase estimation error and ISI dominate the BER error, and the estimation error will cause even severe ISI, which cause the BER even worse.

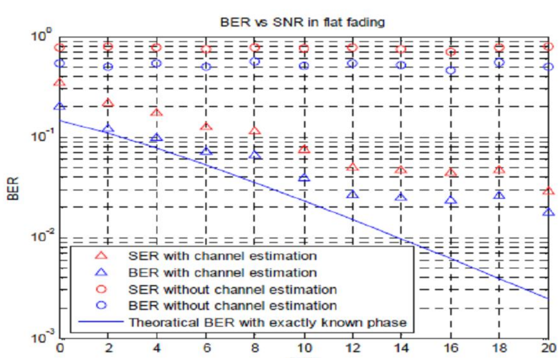


Fig. 13 BER of simulation vs theoretical

B. BER & constellation equalized vs non-equalized

In figure 13 and figure 14 the constellation is plot at SNR = 15dB, we see both the BER performance and constellation are greatly improved by channel phase estimation.

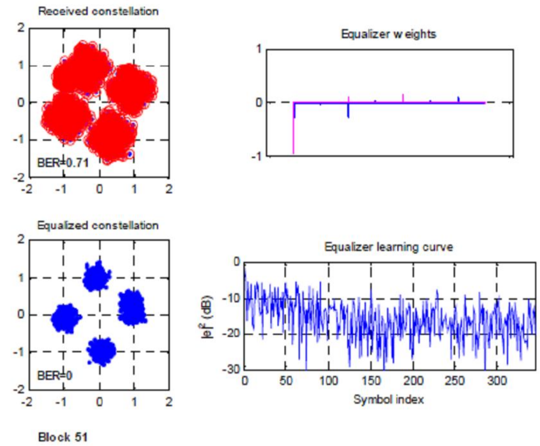


Fig. 14 BER & Constellation of equalized vs nonequal

C. Reset vs continue training result

The BER performances of resetting the state of equalizer come from training result of last coherence time is worse than using the result of last coherence time. The BER is improved by using decision directed mode, since the time-variant property of the channel cause the channel change from estimation result of training data.

D. Training only vs decision directed mode

The BER is improved by using decision directed mode, since the time-variant property of the channel cause the channel change from estimation result of training data.

E. Training only vs decision directed mode

The BER is improved by using decision directed mode, since the time-variant property of the channel cause the channel change from estimation result of training data.

F. LMS vs RLS

The BER performances are almost same for both of them. But during the simulation, we find, LMS need more training data to converge the equalizer comparing to RLS, while latter has more complexity and time consuming.

G. Image quality of received vs original

In figure 15 the received image is plot at SNR = 15dB, we see that other than some random noise and block noise in the image, there are some overlaps in the image. This is due to the white Gaussian noise, phase estimation error in a coherence time, and ISI caused by frequency selective fading channel.

(a)

(b)

Fig. 15 (a) without equalization (b) with equalization

H. BER of Image vs random data

The correlation between image pixels does not affect the BER in frequency selective fading channel, since we use PN code to train the equalizer.

4.4 Comparison among three channels

A. For Image comparison

In figure 16, 17, we may see that in AWGN channel, the image is slight degraded by random noise; in flat fading channel, the image is serious degraded by random noise and block noise; in frequency selective fading channel, the image is very serious degraded by random noise

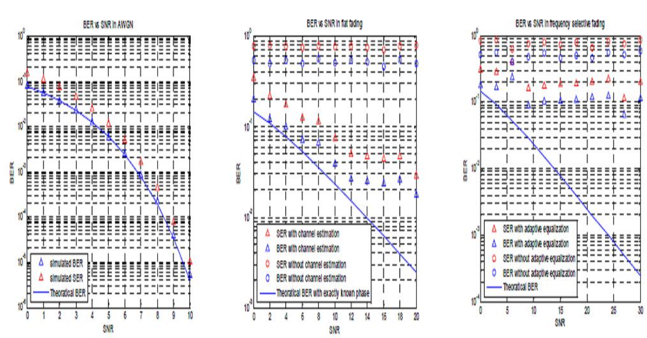
(a)

(b)

(c)

(d)

Fig. 17 (a)Original image (b) AWGN channel (c) Flat fading channel (d) Frequency selective fading channel



(a) (b) (c)

Fig. 17 (a) AWGN channel (b) Flat fading channel (c) Frequency selective fading channel deep spectral nulls in the passband. While frequency selective fading channel normally causes the deep spectral nulls, so in our future simulation, we may improve this by add Decision Feedback Equalization (DFE). In this project, we produce two different scenarios by simulate a GSM carrier frequency and bandwidth, and use pilot data to estimate the channel phase. All of these are simulated in MATLAB at present. In our future model, we may integrate our model into GNU radio with USRP hardware support, which will give a practical environment to test our wireless communications simulation and our own algorithm.

5 CONCLUSION

In this thesis paper, I test the effect of three different channel models, AWGN channel, flat fading channel, and frequency selective fading channel, to the data and image under two scenarios. I also compare and analysis the improvement of channel estimation and adaptive equalization in slow fading channel. Our result is exactly identical to the theoretical analysis. I also improve the receving data and image quality using 4QPSK modulation techniques because it is three time higher data rate then PSK. I also probable future work, which will introduce more research interests.

ACKNOWLEDGMENT

The The authors would like to thank student Md. Farzan Ali [M.Sc.(Tech.)] for her assistance during the computer simulations and for the language checking.

REFERENCES

[1] T. S. Rappaport, "Wireless Communications: Principles and Practice", Second Edition, 2002

[2] J. G. Proakis, "Digital Communications", Fourth Edition, 2001

[3] S. Haykin, "Adaptive Filter Theory", Fourth Edition, 2002

[4] A. V. Oppenheim, R. W. Schafer, J. R. Buck, "Discrete time Signal Processing", Second Edition, 1999

[5] Monsen, P.: 'Adaptive Equalization of the Slow Fading Channel', IEEE Trans., Aug 1974, IT-22, pp. 1064-1075

[6] Ziv, J.: 'Probability of decoding error for random phaseand Rayleigh fading channels', IEEE Trans., Jan 1965, IT-11, pp. 53- 61

[7] M. Pukkila, "Channel Estimation Modeling", 2000

[8] CROZIER, S., FALCONER, D., and MAHMOUD, S.:'Shortblock equalization techniques employing channel estimation for fading timedispersive channels'. IEEE Vehicular Technology Conference, May 1989, pp.142-146

[9] UNGERBOECK, G.: 'Adaptive maximum-likelihood receiver for carrier-modulated data-transmission systems

[10] Do-Sik Yoo; Hafeez, A.; Stark, W.E., "Trellis-based multiuser detection for DS-CDMA systems with frequency-selective fading, " Wireless Communications and Networking Conference, IEEE, 1999, vol.2. pp. 829 –833.

[11] J. G. Proakis, Digital Communication, 3rd edition,McGraw-hill,1995.

[12] W. C. Jakes, "Microwave mobile communication," IEEE Press Classis Reisse, 1974.

Biography

Md. Sipon Miah received the Bachelor's and Master's Degree in the Department of Information and Communication Engineering from Islamic University, Kushtia, in 2006 and 2007, respectively. He is currently Lecturer in the department of ICE, Islamic University, Kushtia-7003, Bangladesh. Since 2003, he has been a Research Scientist at the Communication Reasearch Laboratory, Department of ICE, Islamic University, Kushtia, where he belongs to the spread-spectrum research group. He is pursuing research in the area of internetworking in wireless communication. He has three published paper in international and two national journals in the same areas. His areas of interest include database system, optical fiber communication, Spread Spectrum and mobile communication.

M. Mahbubur Rahman received the Bachelor's and Master's Degree in Physics, Rajshahi University, in 1983, 1994 and PhD degree in Computer Science & Engineering in 1997. He is courrently Professor in the department of ICE, Islamic University, Kushtia-7003, Bangladesh. He has twenty four published papers in international and national journals. His areas of interest include internetworking, AI & mobile communication.

Tapan Kumar Godder received the Bachelor's, Master's and M.Phil degree in Applied Physics & Electronics from Rajshahi University, Rajshahi in 1994, 1995 and 2007, respectively. He is currently Associate Professor in the department of ICE, Islamic University, Kushtia-7003, Bangladesh. He has seventeen published papers in international and national journals. His areas of interest include internetworking, AI & mobile communication.

Bikash Chandran Singh received the Bachelor's and Master's Degree in Information and Communication Engineering from Islamic University, Kushtia, in 2005 and 2007, respectively. He is currently Lecturer in the department of ICE, Islamic University, Kushtia-7003, Bangladesh. His areas of interest include database, optical fiber communication & multimedia.

Mst. Tania Parvin received the Bachelor's Degree in Information and Communication Engineering from Islamic University, Kushtia, in 2009. She is currently a M.Sc student in the department of ICE, Islamic University, Kushtia-7003, Bangladesh.