East West University

Faculty of

Electronics and Communication Engineering

“Performance Improvement of Fiber Wireless (Fi-Wi) Network by using Multi-hop Relay System over Noise”

A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Electronics and Telecommunication Engineering.

Submitted By

Hasin Zahan

ID: 2013-1-55-035

&

Ireen Sarker Sefa

ID: 2013-1-55-024

Supervisor

Mustafa M. Hussain

Assistant Professor

Department of Electronics and Communication Engineering

Supervisor's Statement

Hereby I confirm that the present project was prepared under my supervision and that is fulfills all the requirements for the Bachelor degree of Electronics & Telecommunication Engineering.

………………………

Date

…………………………

Supervisor's Signature

DECLARATION

Hereby We Declare that the present project was prepared by us and none of its contents was obtained by means that are against the law.

The project has never before been a subject of any procedure of obtaining an academic degree.

Moreover, we declared that the current version of the project is identical.

………………… ……………………….

Hasin Zahan Ireen Sarker Sefa

Signature of Supervisor's	**Signature of Dept. Chairperson**
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Mustafa M. Hussain Assistant Professor Dept. of Electronics and Communication Engineering, East West University.	**Dr. Md. Mofazzal Hossain** Professor & Chairperson Dept. of Electronics and Communication Engineering, East West University.

Acknowledgement

First we would like to express our sincere gratitude to Allah that we could complete our project. Then we are externally grateful to parents for their constant support through put our academic work.

We are extremely fortunate towards our supervisor Mustafa Mahmud Hussain for helping us throughout the project. He helped us in every possible way for completing our project.

We are also thanks to our classmates for inspiring us and helping us to choose Performance Improvement of Fiber Wireless (Fi-Wi) Network by using Multi-hop Relay System over Noise.

Abstract

Fiber-wireless (Fi-Wi) networks are a viable solution for delivering high profile quadruple play services. Integration of Passive optical networks (PON) networks along with wireless access networks provide ubiquitous characteristics for high bandwidth applications. PON operation can be improved by employing an improved digital modulation techniques. One of it is multi-hoped relay architecture that improves the performance of optical-wireless access networks. Because transmit diversity is not practically possible to the cellular mobile station due to the small size of the mobile station and electromagnetic interaction of antenna elements on the small platform .So, there is a need for such ideas to be extended to the macroscopic arena[1], where space-time coding is performed over transmit antennas that are not necessarily co-located. Mobile antennas are Omni directional. Signals transmitted towards the destination can be “overheard” at the other Mobile Terminals (Partner). Partners (Adjacent Mobile Terminals) process this overheard information and re-transmit towards the destination. This approach successfully gives solution to the problem of just one receiving antenna in a handset. In particular, the end-to-end bit-error rate (BER) of relaying mobile station is simulated. This paper proposes a novel feedback-based multi-hopped relay network over noise effect to offers better solution for Passive optical networks.

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1

Introduction

Nowadays the interest in high data-rate and demand for wireless broadband communication is growing rapidly. The congestion and the limitation of radio spectrum bandwidth have initiated growth of integrated optical and wireless networks [2]. Fiber-wireless (Fi-Wi) access networks also referred to as wireless-optical broadband access networks (WOBANs), combine the reliability, robustness, and high capacity of optical fiber networks and the flexibility, ubiquity, and cost savings of wireless networks [3]. The Fi-Wi network is a combination of optical backend and wireless front end.

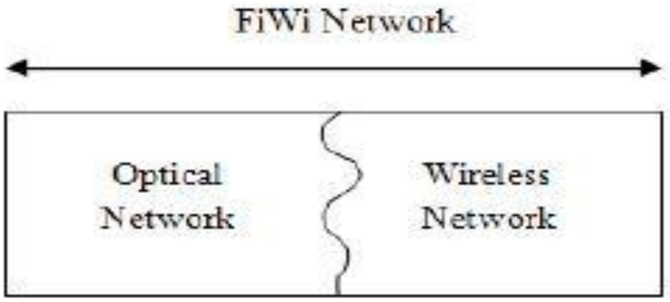


Fig.1 Fi-Wi Concept

The ultimate goal of Fiber-Wireless (FiWi) networks is the convergence of various optical and wireless technologies under a single infrastructure in order to take advantage of their complementary features and therefore provide a network capable of supporting bandwidth-hungry emerging applications in a seamless way for both fixed and mobile clients.

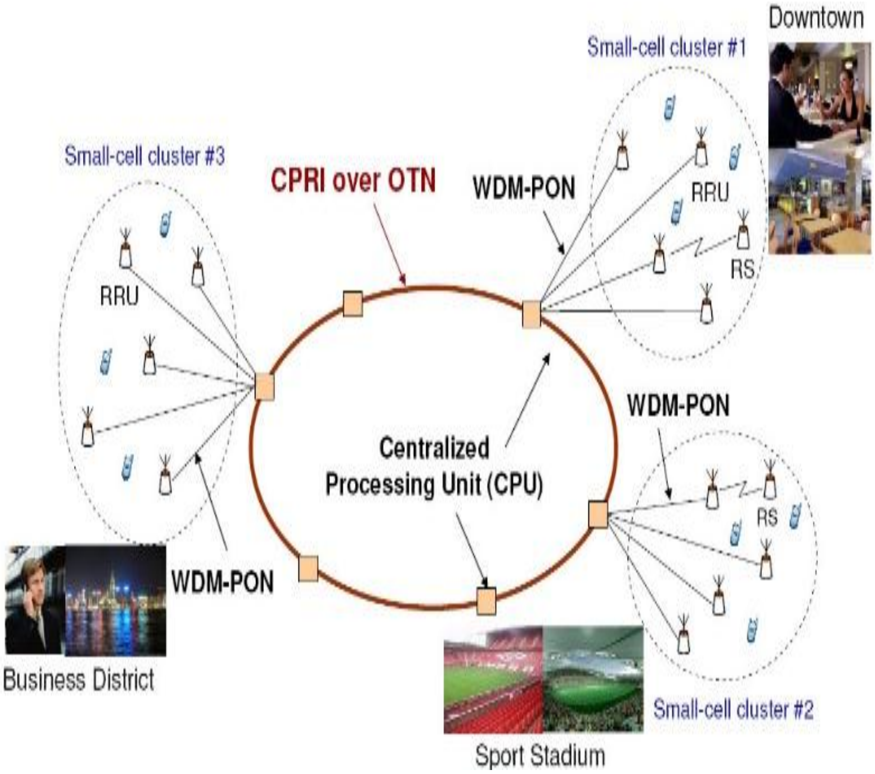


Fig .2 Fi-Wi Model.

The Fi-Wi architecture is based on radio fiber (R&F) network integration,an approach that is different from radio over fiber proposal. It distinguishes Fi-Wi R&F architectures based on three level network deployment of different optical and wireless technologies and classifies them based on technology used in the first level network.

Chapter

2

Fiber-Wireless (FiWi) Broadband Access Networks

Future broadband access networks will be bimodal, capitalizing on the respective strengths of both optical and wireless technologies and smartly merging them in order to realize future-proof Fiber-Wireless (FiWi) networks that strengthen our information society while avoiding its digital divide. By combining the capacity of optical fiber networks with the ubiquity and mobility of wireless networks, FiWi networks form a powerful platform for the support and creation of emerging as well as future unforeseen applications and services, e.g., telepresence. FiWi networks hold great promise to change the way we live and work by replacing commuting with teleworking. This not only provides more time for professional and personal activities for corporate and our own personal benefit, but also helps reduce fuel consumption and protect the environment, issues that are becoming increasingly important in our lives.

Optical networks offer a huge capacity but with high implementation cost while wireless network offer mobility with low rates and via error prone channels. This idea of combining these two networks is very attractive since it would allow exploitation of complementary benefits of both the technologies .This idea lead to Fi-Wi network proposal where optical and wireless technologies form a common integrated infrastructure capable of supporting upcoming applications and services while offering seamless mobility to the clients.

Fi-Wi Structure & Classification

2.1 Network Structure

Fi-Wi consists of four major units: OLT(Optical Line Terminal),ONU-MPP(Optical Network Unit-Mesh Portal Point),MAP(Mesh Access Point),STA(Subscribers Station) .

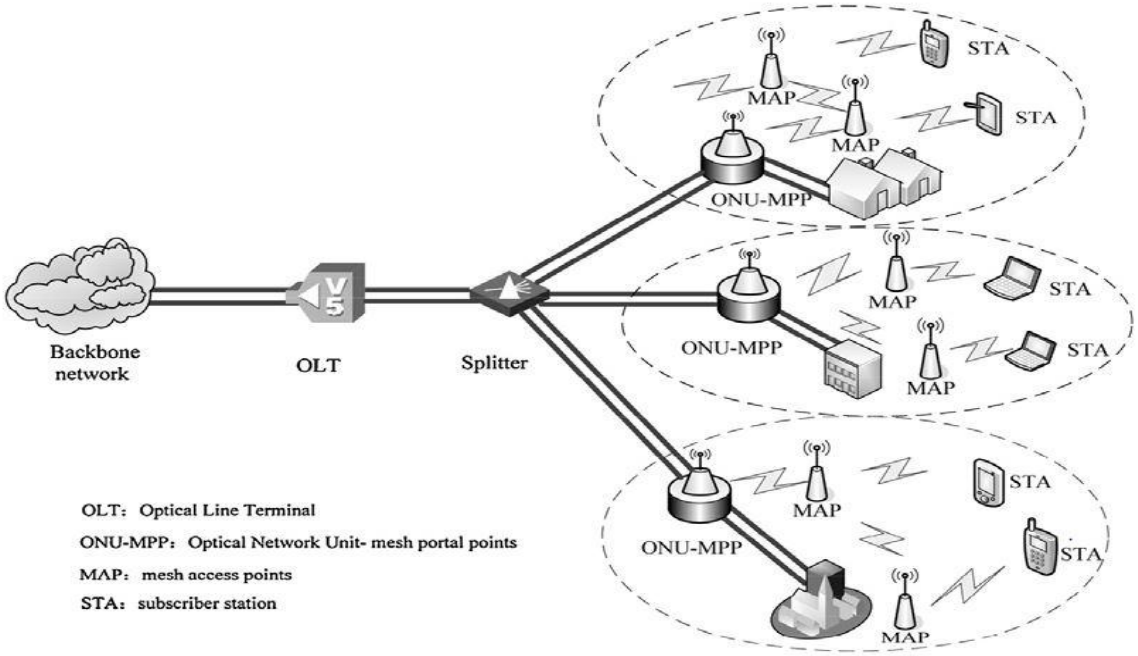


Fig.3 Fi-Wi Structure

An **Optical Line Termination** (**OLT**), also called an **optical line terminal**, is a device which serves as the service provider endpoint of apassive optical network. It provides two main functions:

- To perform conversion between the electrical signals used by the service provider's equipment and the fiber optic signals used by the passive optical network.

- To coordinate the multiplexing between the conversion devices on the other end of that network (called either optical network terminals or optical network units).

An **Optical Network Terminal (ONT)**, also called an **optical network unit**,is used to terminate the fiber optic line, de-multiplex the signal into its component parts (voice telephone, television, and Internet), and provide power to customer telephones. As the ONT must derive its power from the customer premises electrical supply, many ONTs have the option for a battery backup, to maintain service in the event of a power outage.[4]

Mesh APs learn about their environment when they boot up. Mesh APs are either configured as a mesh portal (MPP), an AP that uses its wired interface to reach the controller, or a mesh point (MP), an AP that establishes an all-wireless path to the mesh portal. Mesh APs locate and associate with their nearest neighbour, which provides the best path to the mesh portal. Mesh portals and mesh points are also known as mesh nodes, a generic term used to describe APs configured for mesh.

2.2 Network Classification

Fi-Wi Network is classified into two types: Radio & Fiber (R&F) Network, Radio over Fiber (RoF) Network:

RoF networks have been studied for many years as an approach to integrate optical fiber and wireless networks. In RoF networks, radiofrequencies (RFs) are carried over optical fiber links between a central station and multiple low-cost remote antenna units (RAUs) in support of a variety of wireless applications. For instance, a distributed antenna system connected to the base station of a microcellular radio system via optical fibers was proposed in. To efficiently support timevarying traffic between the central station and its attached base stations, a centralized dynamic channel assignment method is applied at the central station of the proposed fiber optic microcellular radio system. To avoid having to equip each radio port in a fiber optic microcellular radio network with a laser and its associated circuit to control the laser parameters such as temperature, output power, and linearity, a costeffective radio port architecture deploying remote modulation can be used. Apart from realizing low-cost microcellular radio networks, optical fibers can also be used to support a wide variety of other radio signals. RoF networks are attractive since they provide transparency against modulation techniques and are able to support various digital formats and wireless standards in a cost-effective manner.

2.2.1 **Radio-and-Fiber(R&F) Network:** R&F-based FiWi access networks may deploy a number of enabling optical and wireless technologies. a) Optical Technologies: Apart from PONs, the following optical technologies are expected to play an increasingly important role in the design of a flexible and cost-effective optical backhaul for FiWi networks. b) Wireless Technologies: A plethora a broadband wireless access technologies exist [18]. Currently, the two most important ones for the implementation of the wireless part of FiWi networks are WiFi and WiMAX. Protocol translation might be done at the interface of optical and wireless segments by an appropriate optical-wireless device, such as Optical Network Unit – Base Station (ONU-BS), or at the optical part, e.g., by an Optical Line Terminal (OLT), in a Passive Optical Network (PON).

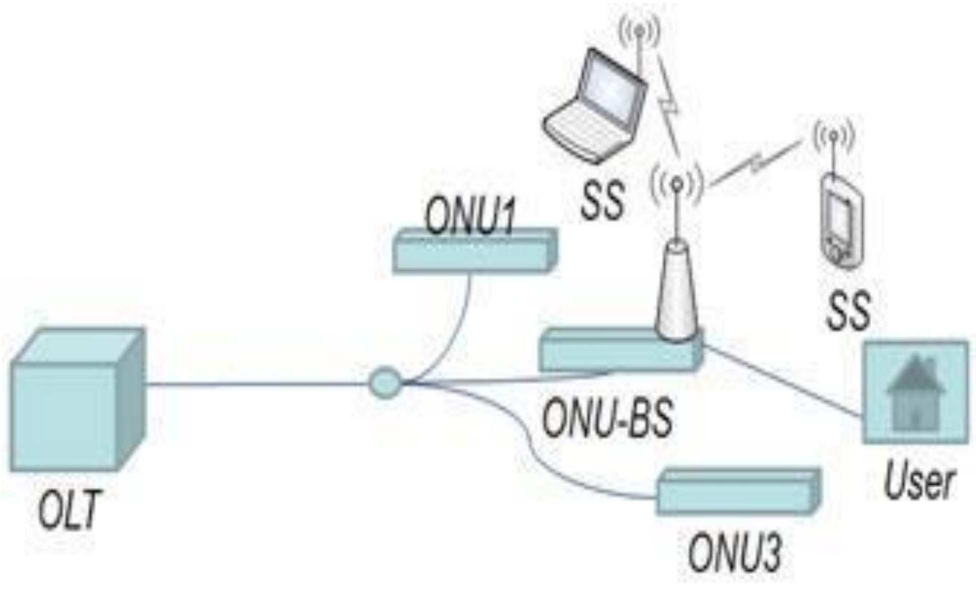


Fig.4 Example of R&F Fi-Wi broadband access network architecture

2.2.2 Radio-over-Fiber (RoF) Network: Several RoF technologies have been emerging for the realization of low-cost FiWi networks. In the following, we briefly summarize some of the key enabling RoF technologies. For further details and a technically more profound discussion, we refer the interested reader to.

a) Optical RF Generation: To avoid the electronic bottleneck, the generation of RF signals is best done optically.

b) Remote Modulation: An interesting approach to build low-cost FiWi networks is the use of a single light source at the central office (CO) to generate a downlink wavelength that is reused at RAUs for upstream transmission by means of remote modulation, thereby avoiding the need for an additional light source at each RAU.

The required protocol translation is done in the optical part by an appropriate optical element, e.g., OLT.

- Flexibility
- Centralized maintenance
- Cost-effective and fast deployment

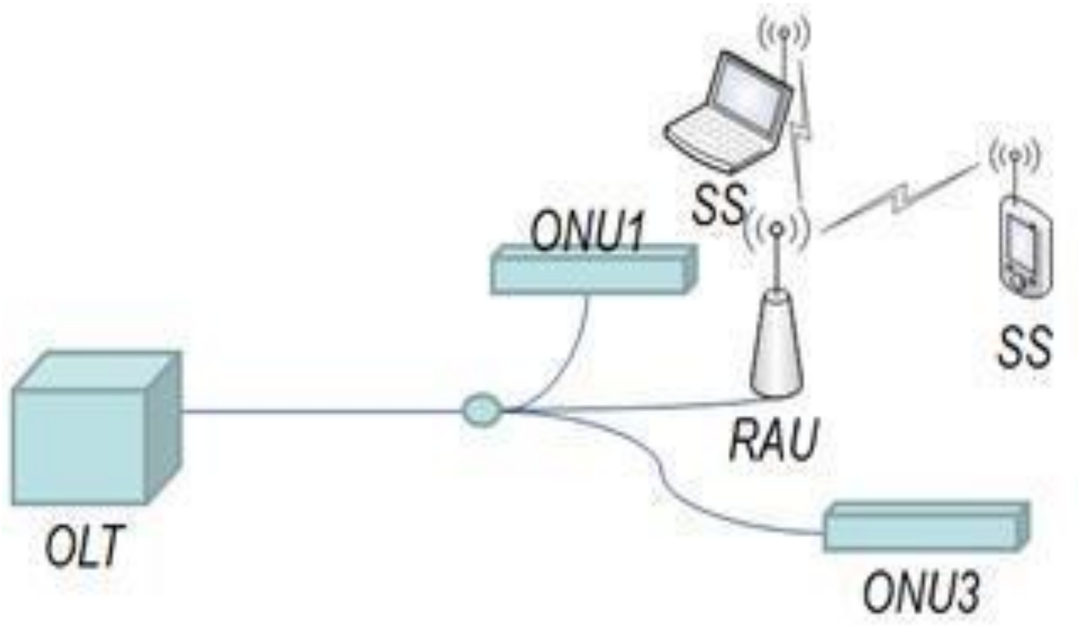


Fig.5 Example of RoF Fi-Wi broadband access network architecture

The special and unique characteristics of FiWi broadband networks attract us to design a novel FiWi architecture with ability of providing end-to-end QoS connectivity for both wireless and optical subscribers. Some of the characteristics of FiWi access networks are as follows:

Architecture

- Reduces costs and increases flexibility

Reconfigurability

- Allows for demand change among districts
- Improves network performance in terms of throughput, connectivity, and QoS

- One solution: Wavelength Division Multiplexing PON (WDM PON)

Load balancing

- Renders FiWi networks robust

Routing

- Plays a key role in wireless mesh networks which render robust wireless segment in FiWi access networks

Cost-efficiency and Migration

- Future-proofness by providing cautious pay-as-you-grow migration
- Backward compatibility with implemented standards as well as interoperability with future technologies

User-friendliness

- Autonomic FiWi networks: Self-configuring, Self-protecting, Self-optimizing, and Self-healing.

Network Planning and Reconfiguration

To maximize the performance of FiWi networks and minimize their deployment costs, network planning and reconfiguration play a key role in achieving these design objectives. In this section, we describe a number of algorithms that help solve important FiWi network planning problems related to the optimal placement of ONUs, mitigation of the detrimental impact of wireless interferences for peer-to-peer communications between wireless end-users, and architectural modifications for the support of direct inter-ONU communications.

Chapter

3

Multi-hopped Relaying

In Fi-Wi Network, ONU to STS or SS Part is consists of Wireless Communication. In this part, we have proposed to use multi-hopped relaying model.

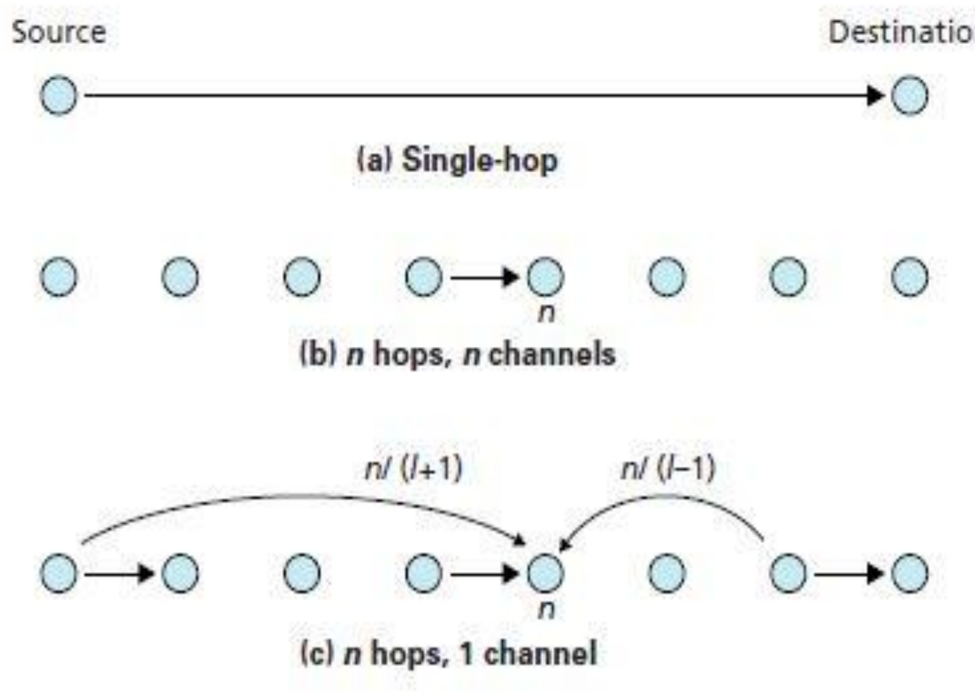


Fig.6 Multi-hop Relaying Model

Multi-hopped relaying means differentiating the source part to destination part into various nodes and relaying them to improve the performance in wireless communication for Digital Modulation Schemes.

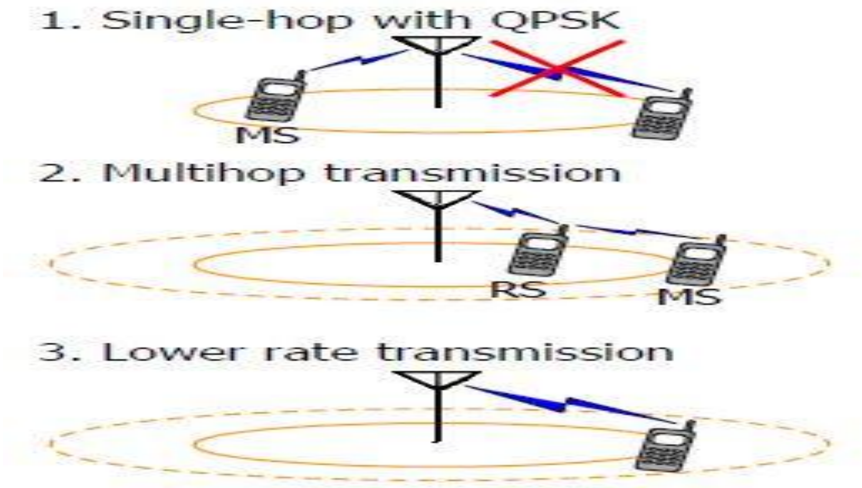


Fig.7 Multi-hop Relaying using Relay Station(RS)[7]

In this paper we have proposed a model for multi-hopped relay network based Digital Modulation Schemes over noise for Fi-Wi Networks.

Chapter

4

4.1 System Model

Mobile antennas are omni directional. Signals transmitted towards the destination can be “overheard” at the other Mobile Terminals (Partner). Partners (Adjacent Mobile Terminals) process this overheard information and re-transmit towards the destination. These Partnering mobiles form a Virtual Antenna Array[5]. This approach successfully gives solution to the problem of just one receiving antenna in a handset. The idea is to relay the information from the source Mobile Terminals to the (BS) antenna array using a variable number of relaying Mobile Terminals. The effect of different possible configurations on the performance in terms of bit error rate (BER) versus signal-to-noise ratio (SNR) is analyzed. The results are very promising in the initial stage of development.

Lets consider a two relay system. The Source- Mobile Terminal wants to communicate with target T- Mobile Terminal. In the first link it will broadcast the information to R- Mobile Terminal to relay information totarget mobile T-MT. [5] [6]

Fig.8 System model with one relaying MT

The signal will go through from Target Mobile Terminal to R- Mobile Terminal with fading h_1 and noise n_1

Relay-Mobile Terminal receives signal, $r_1 = Sh_1 + n_1$

Then R- Mobile Terminal will just relay the information to the target Mobile Terminal. The signal will go through from Relay-Mobile Terminal to Target-Mobile Terminal with fading h_2 and noise n_2.

Target- Mobile Terminal receives, $r_2 = r_1 h_2 + n_2$

4.2 Path Loss Model

In the system, power received by direct transmission is transmission from Source-Mobile Terminal to Target Mobile Terminal without any relaying.[4] [6]

Direct Transmission Power Received, $P_{total} = P(2d)^{\alpha}$

Relayed Transmission Power Received, $P_{total} = 2Pd^{\alpha}$

The total output power is normalized to be able to compare different relaying scheme

Fig. 9 System model with one relaying MT

It was assumed that total transmitted power in the system is limited to S_{TX} the path loss model was assumed to follow traditional exponential behavior where the received power, S_{RX} can be expressed in terms of the pathloss co-efficient as where d= Distance between the transmitter and receiver n is Pathloss co-efficient, C is Constant

$$SNR_{DIRECT} = \frac{S_{Rx}}{N_{Rx}},$$

Denoting the receiver signal to noise ratio (SNR) as

Where S_{Rx} is receiving signal power and N_{RX} is the receiving noise power then SNR of the relaying links i=1,2 can be expressed as, Where α_i is the fraction of power allocated to the i-th relay and $\sum_{i=1}^{n}\alpha_i = 1$. For the communication scenario it is assumed that $d_{relatying,i} = \xi_i d_{dirct}$, where ξ_i is the fractional distance. This guarantees a fair comparison between all, possible relaying schemes as the total power is normalized to the same values.

Chapter

5

Simulation& Results

The system model is simulated for QPSK,BPSK,QAM modulation for Multi-hopped relay network over a SISO (Single-Input-Single-Output) dual-hop relaying communication system. Because the distances between the terminals and the link performance is the same, it was assumed that α_i 1, 2 = 0.5 .

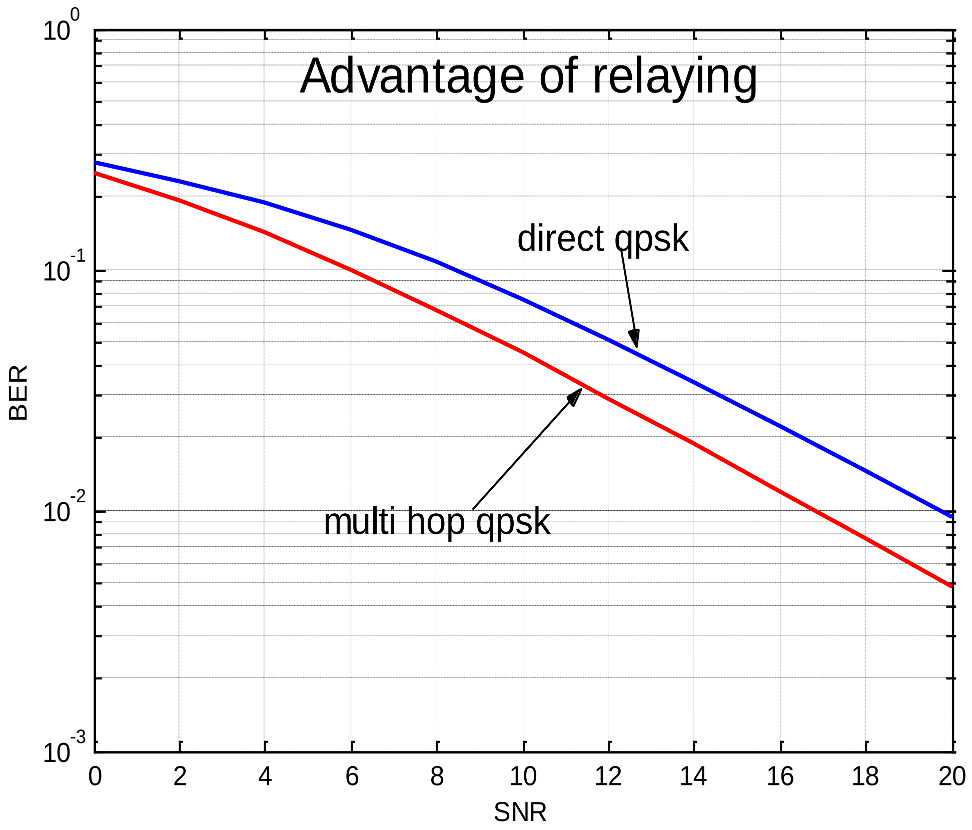


Fig. 10 BER versus SNR for QPSK over a dual-hop SISO communication system.

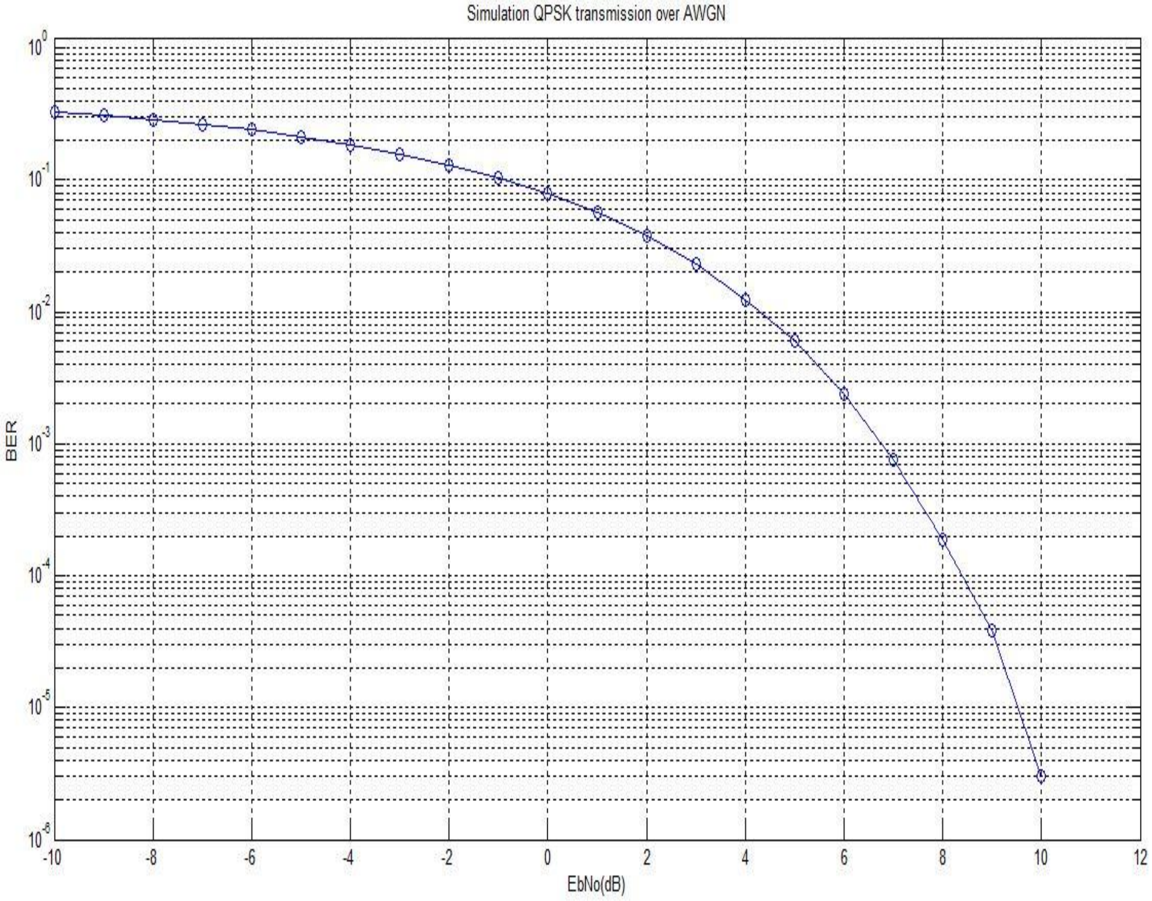


Fig. 11 BER versus SNR for QPSK over a dual-hop SISO communication system(AWGN)

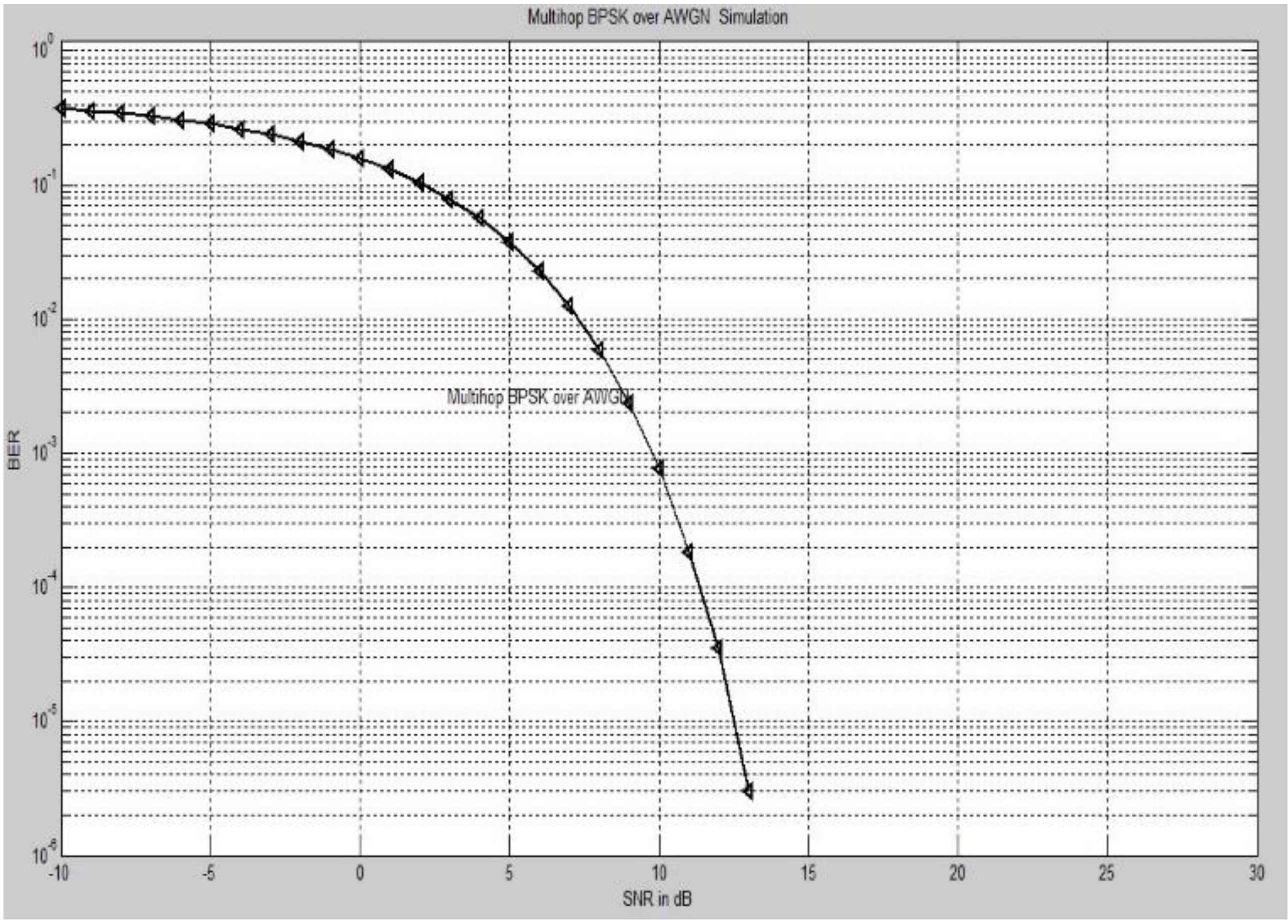


Fig. 12 BER versus SNR for BPSK over a dual-hop SISO communication system(AWGN)

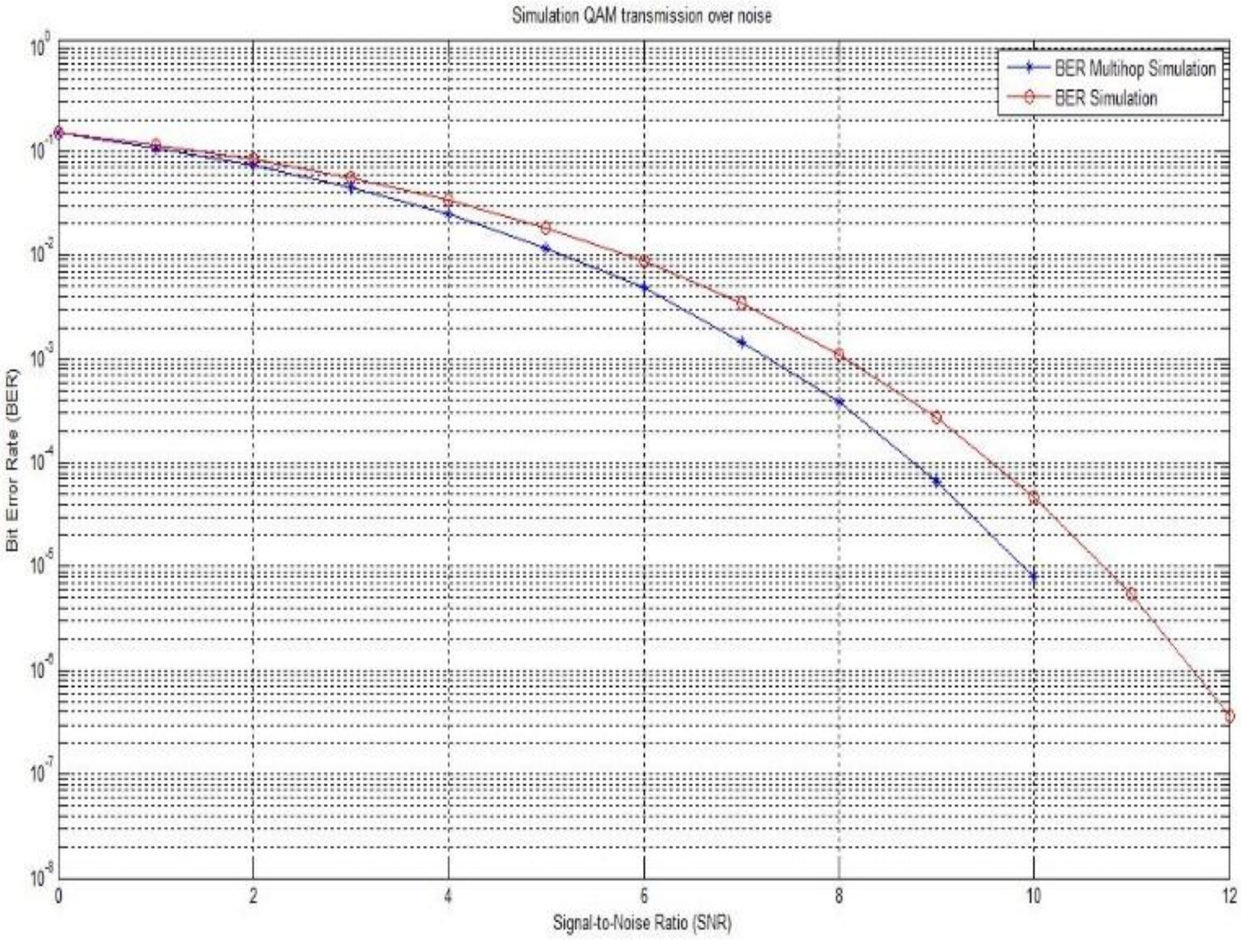


Fig. 13 BER versus SNR for QAM over a dual-hop communication system

The performance is parameterized on the path loss coefficient *n*. From simulation, it has been observed that a relaying system outperforms a system which relies solely on a direct communication link. The simulation result shown that low Transmitter power consumption or high data rates due to relaying.

Chapter

6

Advantage of fiber-wireless (FiWi)

Integrated fiber-wireless (FiWi) access networks aim at taking full advantage of the reliability and high capacity of the optical backhaul along with the flexibility, ubiquity, and cost savings of the wireless/cellular front-end to provide broadband services for both mobile and fixed users. In FiWi access networks, energy efficiency issues must be addressed in a comprehensive fashion that takes into account not only wireless front-end but also optical backhaul segments to extend the battery life of wireless devices and allow operators to reduce their OPEX, while not compromising quality of service (QoS). This paper proposes an energy conservation scheme for FiWi networks (ECO-FiWi) that jointly schedules power-saving modes of wireless stations and access points and optical network units to reduce their energy consumption. ECO-FiWi maximizes the overall network performance by leveraging TDMA to synchronize the power-saving modes and incorporate them into the dynamic bandwidth allocation (DBA) process. A comprehensive energy saving model and an M/G/1 queuing-based analysis of downstream and upstream end-to-end frame delays are presented accounting for both backhaul and front-end network segments. Analytical results show that ECO-FiWi achieves significant amounts of energy saving, while preserving upstream delay and incurring a low delay for downstream traffic.

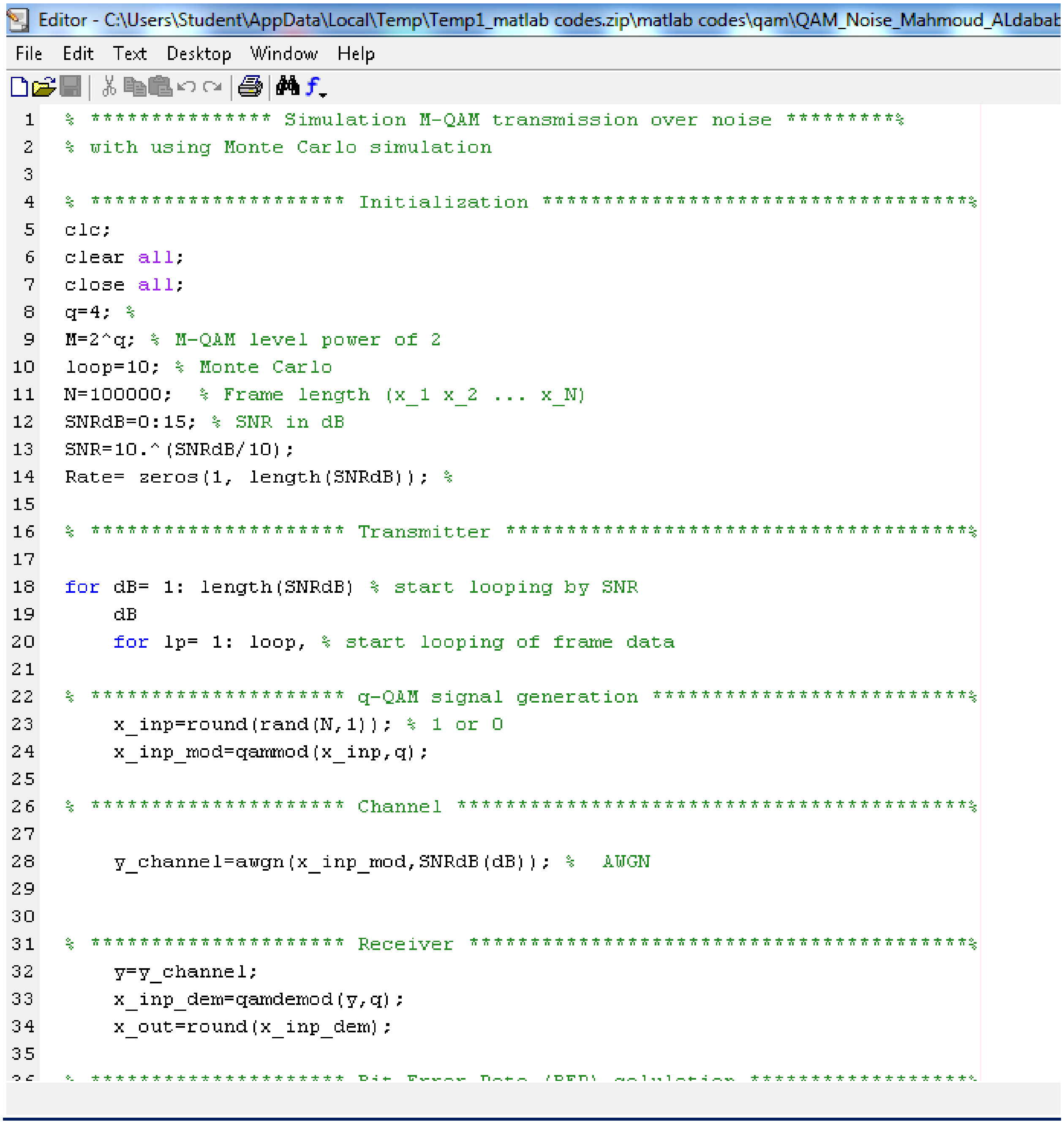
FiWi networks future challenge

Global cellular networks are currently undergoing a major paradigm shift to cope with the unprecedented growth of mobile data traffic driven by the popularity of smart phones and mobile-connected tablets running diverse data-centric applications. In fiber-wireless (FiWi) enhanced LTE-Advanced heterogeneous networks (HetNets), the traditional barriers between coverage-centric mobile networks and capacity-centric FiWi broadband access networks may be removed in order to benefit from fiber backhaul sharing and WiFi offloading. In this paper, we elaborate on emerging trends, identify open key research challenges to unleash the full potential of FiWi enhanced LTE-Advanced HetNets, including their future convergence with other technologies and economic sectors, and attempt to make an educated guess about possible moonshot perspectives for future non-incremental FiWi research.

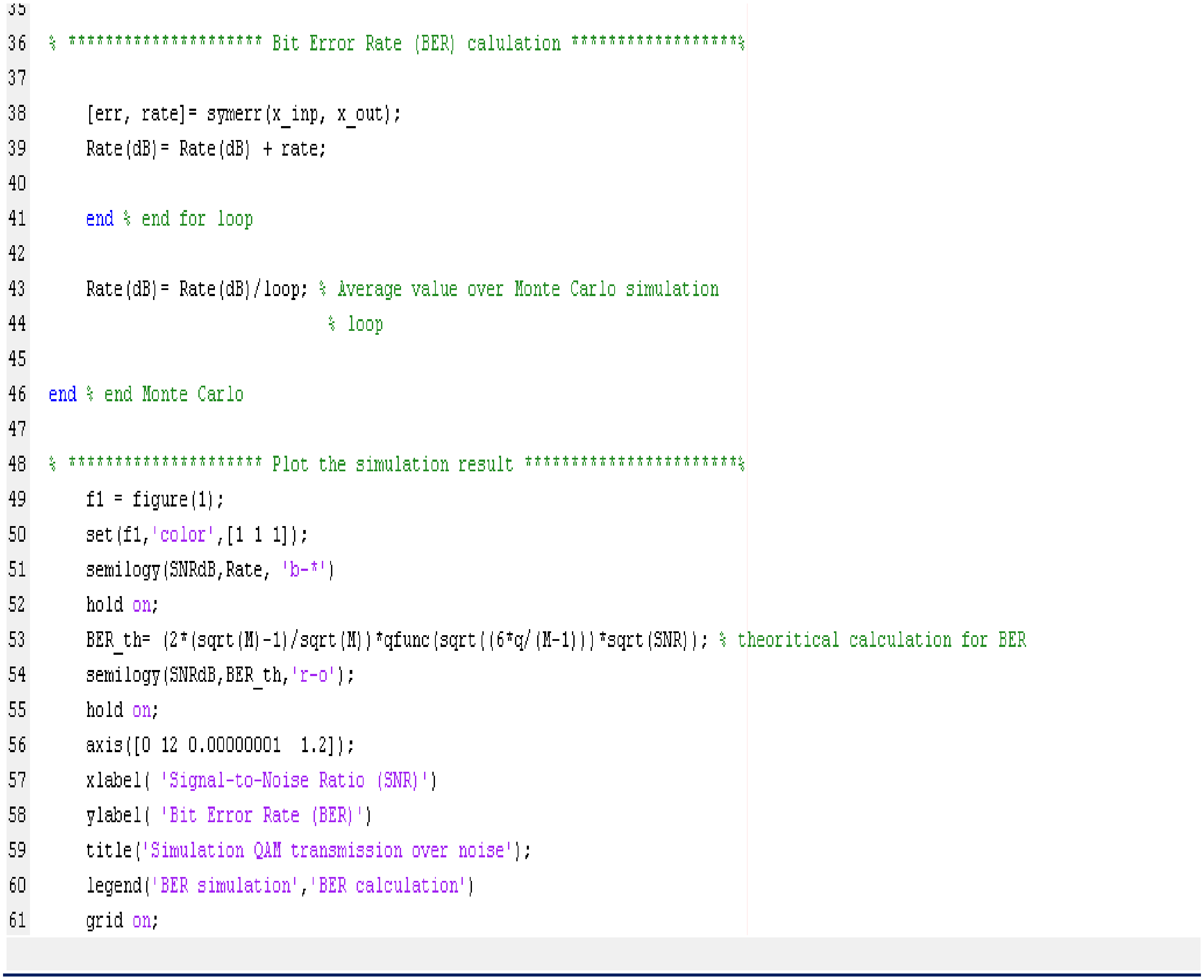
Chapter

7

Code



```matlab
% *************** Simulation M-QAM transmission over noise *********%
% with using Monte Carlo simulation

% ********************* Initialization ***********************************%
clc;
clear all;
close all;
q=4; %
M=2^q; % M-QAM level power of 2
loop=10; % Monte Carlo
N=100000;   % Frame length (x_1 x_2 ... x_N)
SNRdB=0:15; % SNR in dB
SNR=10.^(SNRdB/10);
Rate= zeros(1, length(SNRdB)); %

% ********************* Transmitter **************************************%

for dB= 1: length(SNRdB) % start looping by SNR
    dB
    for lp= 1: loop, % start looping of frame data

% ********************* q-QAM signal generation **************************%
    x_inp=round(rand(N,1)); % 1 or 0
    x_inp_mod=qammod(x_inp,q);

% ********************* Channel ******************************************%

    y_channel=awgn(x_inp_mod,SNRdB(dB)); %  AWGN


% ********************* Receiver *****************************************%
    y=y_channel;
    x_inp_dem=qamdemod(y,q);
    x_out=round(x_inp_dem);

```



```
% ******************** Bit Error Rate (BER) calulation ******************%

    [err, rate]= symerr(x_inp, x_out);
    Rate(dB)= Rate(dB) + rate;

    end % end for loop

    Rate(dB)= Rate(dB)/loop; % Average value over Monte Carlo simulation
                             % loop

end % end Monte Carlo

% ******************** Plot the simulation result **********************%
    f1 = figure(1);
    set(f1,'color',[1 1 1]);
    semilogy(SNRdB,Rate, 'b-*')
    hold on;
    BER_th= (2*(sqrt(M)-1)/sqrt(M))*qfunc(sqrt((6*q/(M-1)))*sqrt(SNR)); % theoritical calculation for BER
    semilogy(SNRdB,BER_th,'r-o');
    hold on;
    axis([0 12 0.00000001  1.2]);
    xlabel( 'Signal-to-Noise Ratio (SNR)')
    ylabel( 'Bit Error Rate (BER)')
    title('Simulation QAM transmission over noise');
    legend('BER simulation','BER calculation')
    grid on;
```

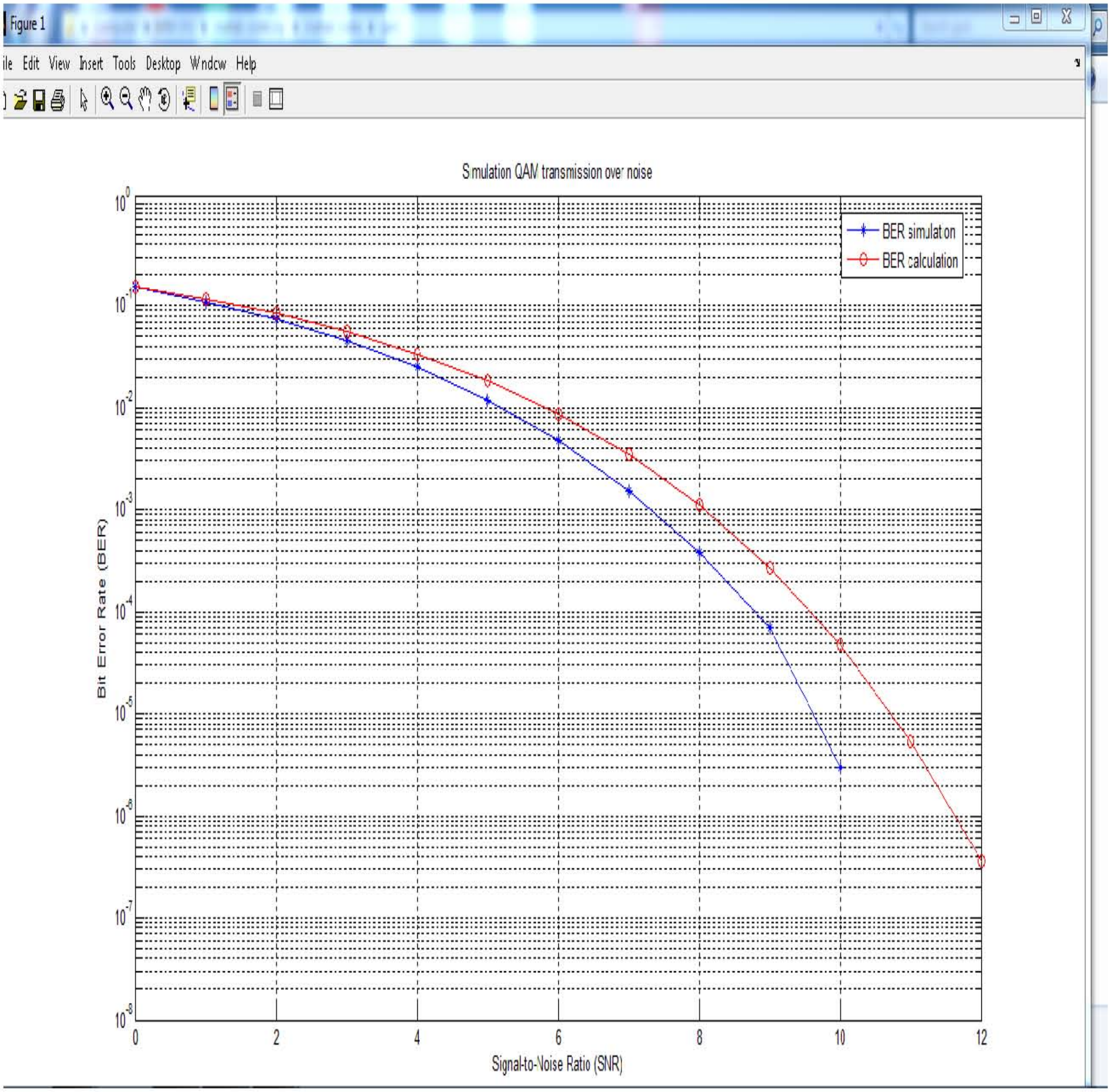


Figure 1
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Simulation QAM transmission over noise
Bit Error Rate (BER)
Signal-to-Noise Ratio (SNR)
BER simulation
BER calculation
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
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4
6
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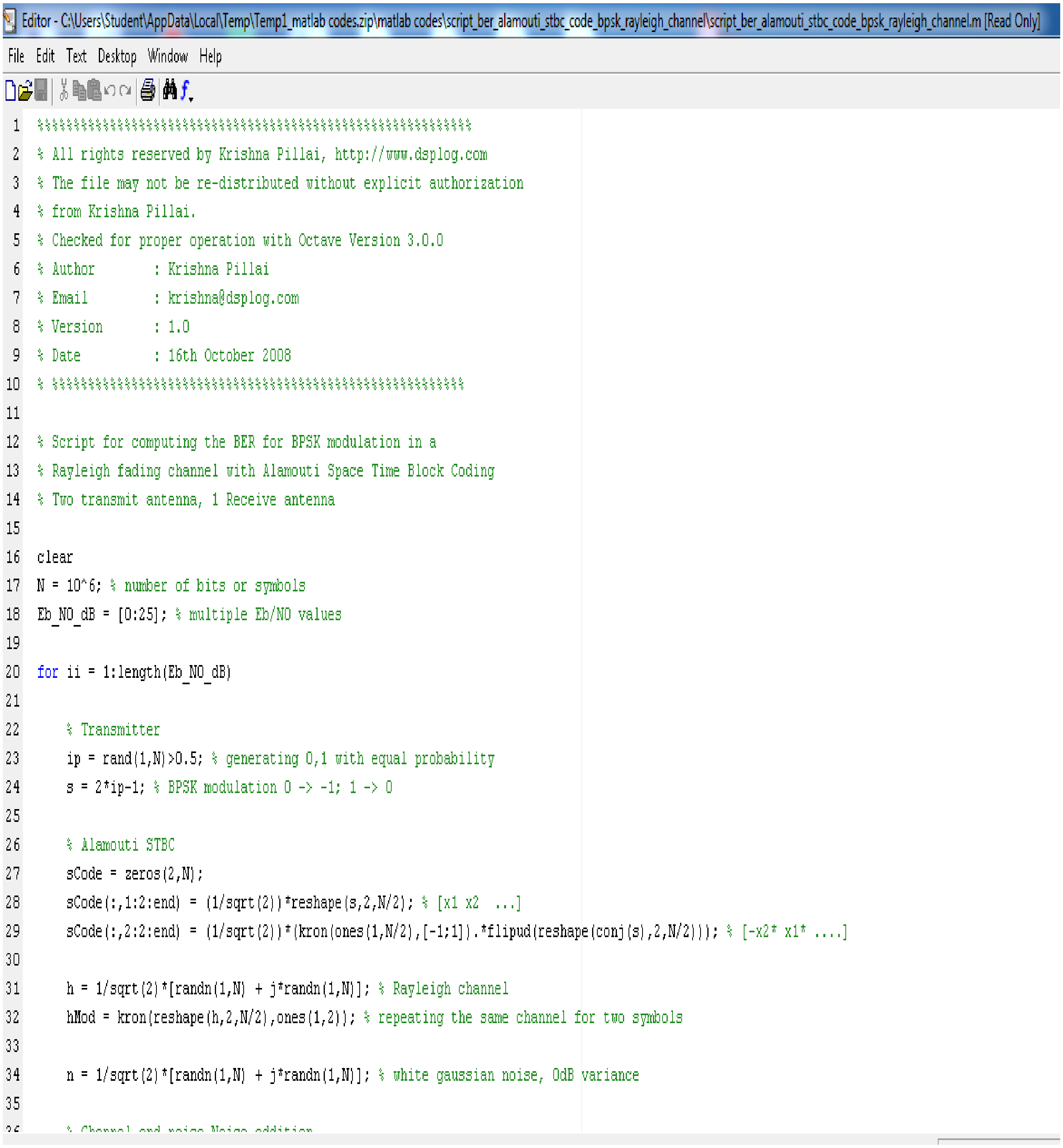
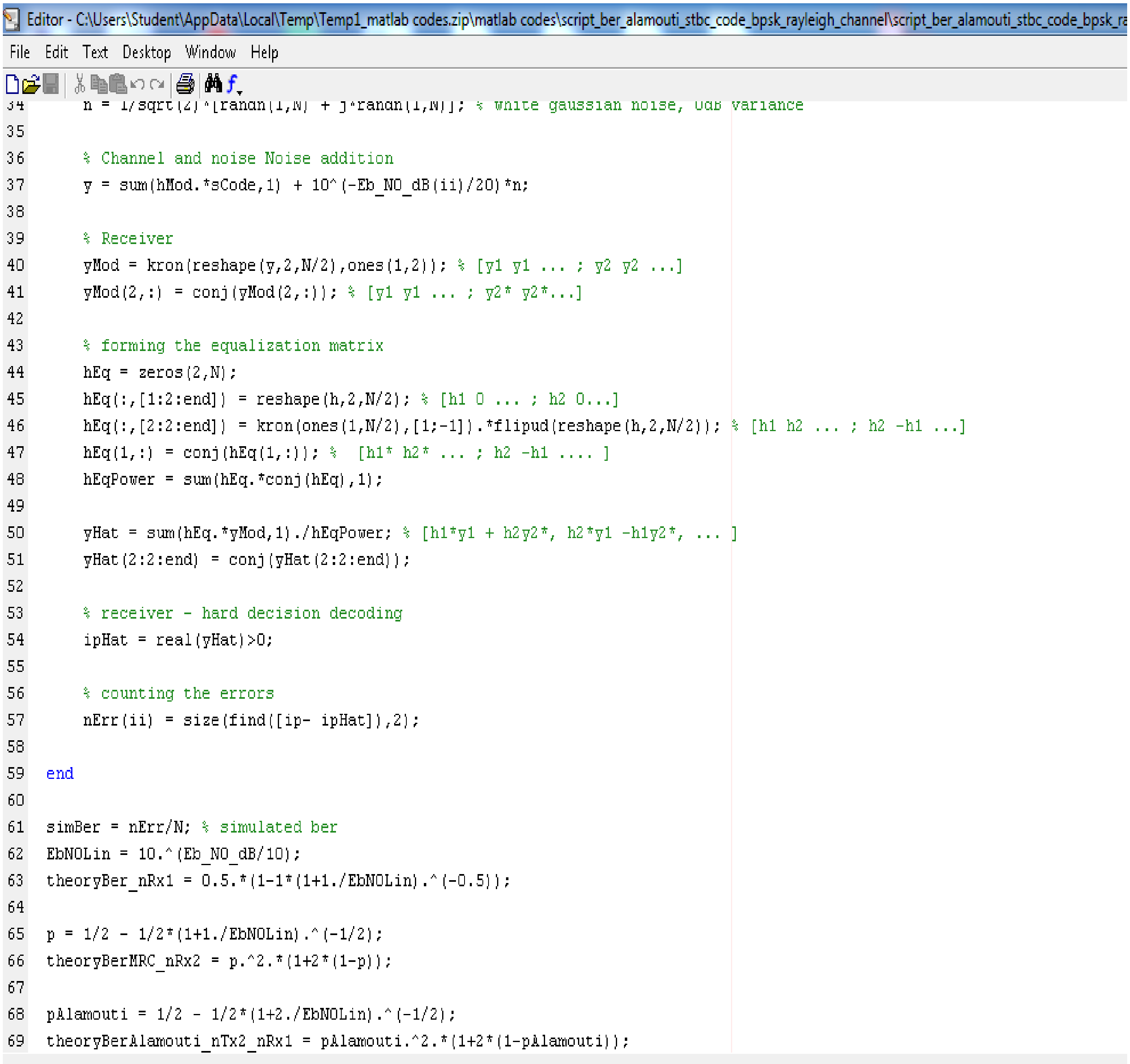
12



```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% All rights reserved by Krishna Pillai, http://www.dsplog.com
% The file may not be re-distributed without explicit authorization
% from Krishna Pillai.
% Checked for proper operation with Octave Version 3.0.0
% Author        : Krishna Pillai
% Email         : krishna@dsplog.com
% Version       : 1.0
% Date          : 16th October 2008
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Script for computing the BER for BPSK modulation in a
% Rayleigh fading channel with Alamouti Space Time Block Coding
% Two transmit antenna, 1 Receive antenna

clear
N = 10^6; % number of bits or symbols
Eb_N0_dB = [0:25]; % multiple Eb/N0 values

for ii = 1:length(Eb_N0_dB)

    % Transmitter
    ip = rand(1,N)>0.5; % generating 0,1 with equal probability
    s = 2*ip-1; % BPSK modulation 0 -> -1; 1 -> 0

    % Alamouti STBC
    sCode = zeros(2,N);
    sCode(:,1:2:end) = (1/sqrt(2))*reshape(s,2,N/2); % [x1 x2  ...]
    sCode(:,2:2:end) = (1/sqrt(2))*(kron(ones(1,N/2),[-1;1]).*flipud(reshape(conj(s),2,N/2))); % [-x2* x1* ....]

    h = 1/sqrt(2)*[randn(1,N) + j*randn(1,N)]; % Rayleigh channel
    hMod = kron(reshape(h,2,N/2),ones(1,2)); % repeating the same channel for two symbols

    n = 1/sqrt(2)*[randn(1,N) + j*randn(1,N)]; % white gaussian noise, 0dB variance

```



```
    n = 1/sqrt(2)*[randn(1,N) + j*randn(1,N)]; % white gaussian noise, 0dB variance

    % Channel and noise Noise addition
    y = sum(hMod.*sCode,1) + 10^(-Eb_N0_dB(ii)/20)*n;

    % Receiver
    yMod = kron(reshape(y,2,N/2),ones(1,2)); % [y1 y1 ... ; y2 y2 ...]
    yMod(2,:) = conj(yMod(2,:)); % [y1 y1 ... ; y2* y2*...]

    % forming the equalization matrix
    hEq = zeros(2,N);
    hEq(:,[1:2:end]) = reshape(h,2,N/2); % [h1 0 ... ; h2 0...]
    hEq(:,[2:2:end]) = kron(ones(1,N/2),[1;-1]).*flipud(reshape(h,2,N/2)); % [h1 h2 ... ; h2 -h1 ...]
    hEq(1,:) = conj(hEq(1,:)); %  [h1* h2* ... ; h2 -h1 .... ]
    hEqPower = sum(hEq.*conj(hEq),1);

    yHat = sum(hEq.*yMod,1)./hEqPower; % [h1*y1 + h2y2*, h2*y1 -h1y2*, ... ]
    yHat(2:2:end) = conj(yHat(2:2:end));

    % receiver - hard decision decoding
    ipHat = real(yHat)>0;

    % counting the errors
    nErr(ii) = size(find([ip- ipHat]),2);

end

simBer = nErr/N; % simulated ber
EbN0Lin = 10.^(Eb_N0_dB/10);
theoryBer_nRx1 = 0.5.*(1-1*(1+1./EbN0Lin).^(-0.5));

p = 1/2 - 1/2*(1+1./EbN0Lin).^(-1/2);
theoryBerMRC_nRx2 = p.^2.*(1+2*(1-p));

pAlamouti = 1/2 - 1/2*(1+2./EbN0Lin).^(-1/2);
theoryBerAlamouti_nTx2_nRx1 = pAlamouti.^2.*(1+2*(1-pAlamouti));
```

```
pAlamouti = 1/2 - 1/2*(1+2./EbN0Lin).^(-1/2);
theoryBerAlamouti_nTx2_nRx1 = pAlamouti.^2.*(1+2*(1-pAlamouti));

close all
figure
semilogy(Eb_N0_dB,theoryBer_nRx1,'bp-','LineWidth',2);
hold on
semilogy(Eb_N0_dB,theoryBerMRC_nRx2,'kd-','LineWidth',2);
semilogy(Eb_N0_dB,theoryBerAlamouti_nTx2_nRx1,'c+-','LineWidth',2);
semilogy(Eb_N0_dB,simBer,'mo-','LineWidth',2);
axis([0 25 10^-5 0.5])
grid on
legend('theory (nTx=1,nRx=1)', 'theory (nTx=1,nRx=2, MRC)', 'theory (nTx=2, nRx=1, Alamouti)', 'sim (nTx=2, nRx=1, Alamouti)');
xlabel('Eb/No, dB');
ylabel('Bit Error Rate');
title('BER for BPSK modulation with Alamouti STBC (Rayleigh channel)');
```

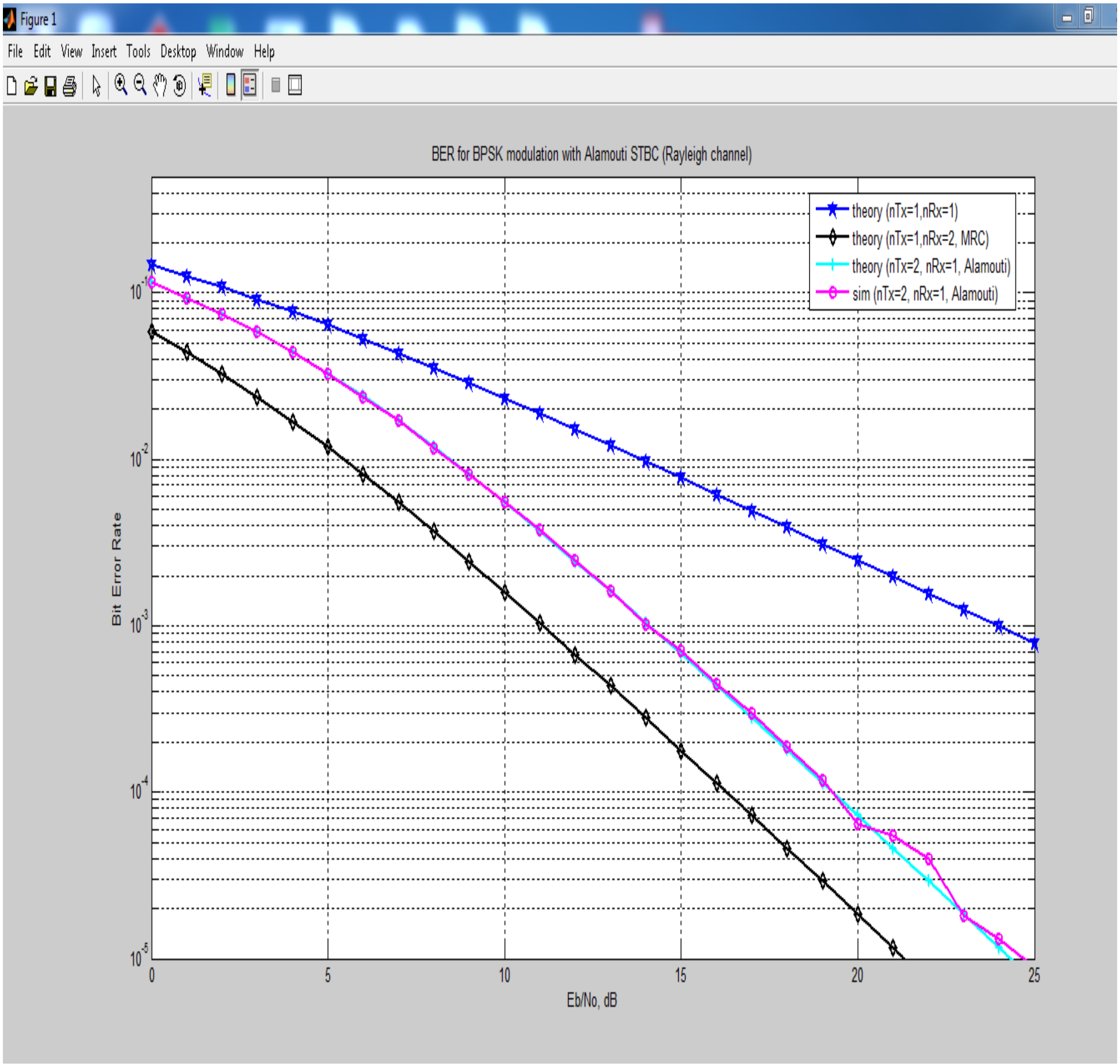
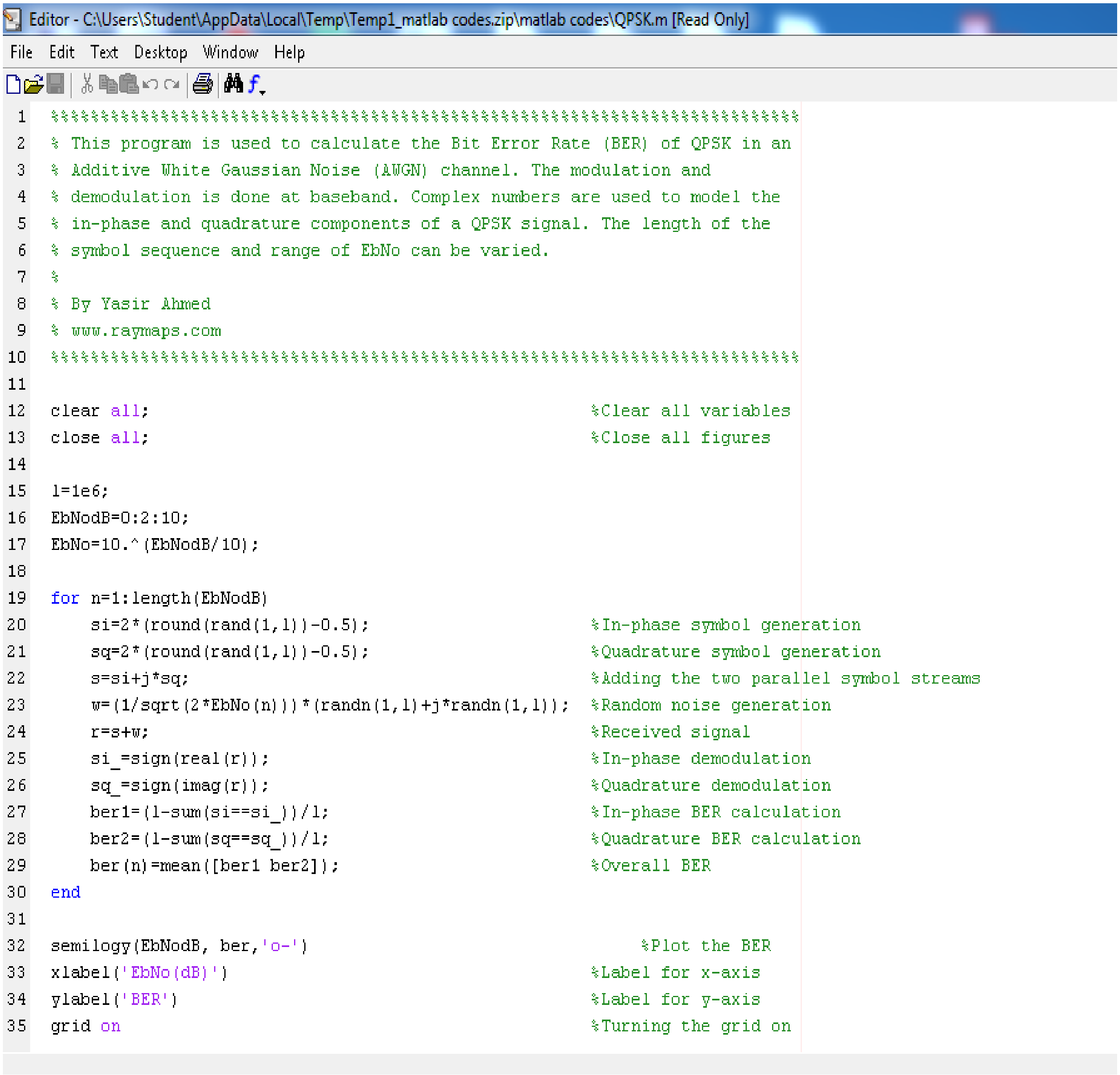


Figure 1
File Edit View Insert Tools Desktop Window Help
BER for BPSK modulation with Alamouti STBC (Rayleigh channel)
theory (nTx=1,nRx=1)
theory (nTx=1,nRx=2, MRC)
theory (nTx=2, nRx=1, Alamouti)
sim (nTx=2, nRx=1, Alamouti)
Bit Error Rate
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
5
10
15
20
25
Eb/No, dB



```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% This program is used to calculate the Bit Error Rate (BER) of QPSK in an
% Additive White Gaussian Noise (AWGN) channel. The modulation and
% demodulation is done at baseband. Complex numbers are used to model the
% in-phase and quadrature components of a QPSK signal. The length of the
% symbol sequence and range of EbNo can be varied.
%
% By Yasir Ahmed
% www.raymaps.com
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all;                                            %Clear all variables
close all;                                            %Close all figures

l=1e6;
EbNodB=0:2:10;
EbNo=10.^(EbNodB/10);

for n=1:length(EbNodB)
    si=2*(round(rand(1,l))-0.5);                      %In-phase symbol generation
    sq=2*(round(rand(1,l))-0.5);                      %Quadrature symbol generation
    s=si+j*sq;                                        %Adding the two parallel symbol streams
    w=(1/sqrt(2*EbNo(n)))*(randn(1,l)+j*randn(1,l));  %Random noise generation
    r=s+w;                                            %Received signal
    si_=sign(real(r));                                %In-phase demodulation
    sq_=sign(imag(r));                                %Quadrature demodulation
    ber1=(l-sum(si==si_))/l;                          %In-phase BER calculation
    ber2=(l-sum(sq==sq_))/l;                          %Quadrature BER calculation
    ber(n)=mean([ber1 ber2]);                         %Overall BER
end

semilogy(EbNodB, ber,'o-')                                 %Plot the BER
xlabel('EbNo(dB)')                                    %Label for x-axis
ylabel('BER')                                         %Label for y-axis
grid on                                               %Turning the grid on
```

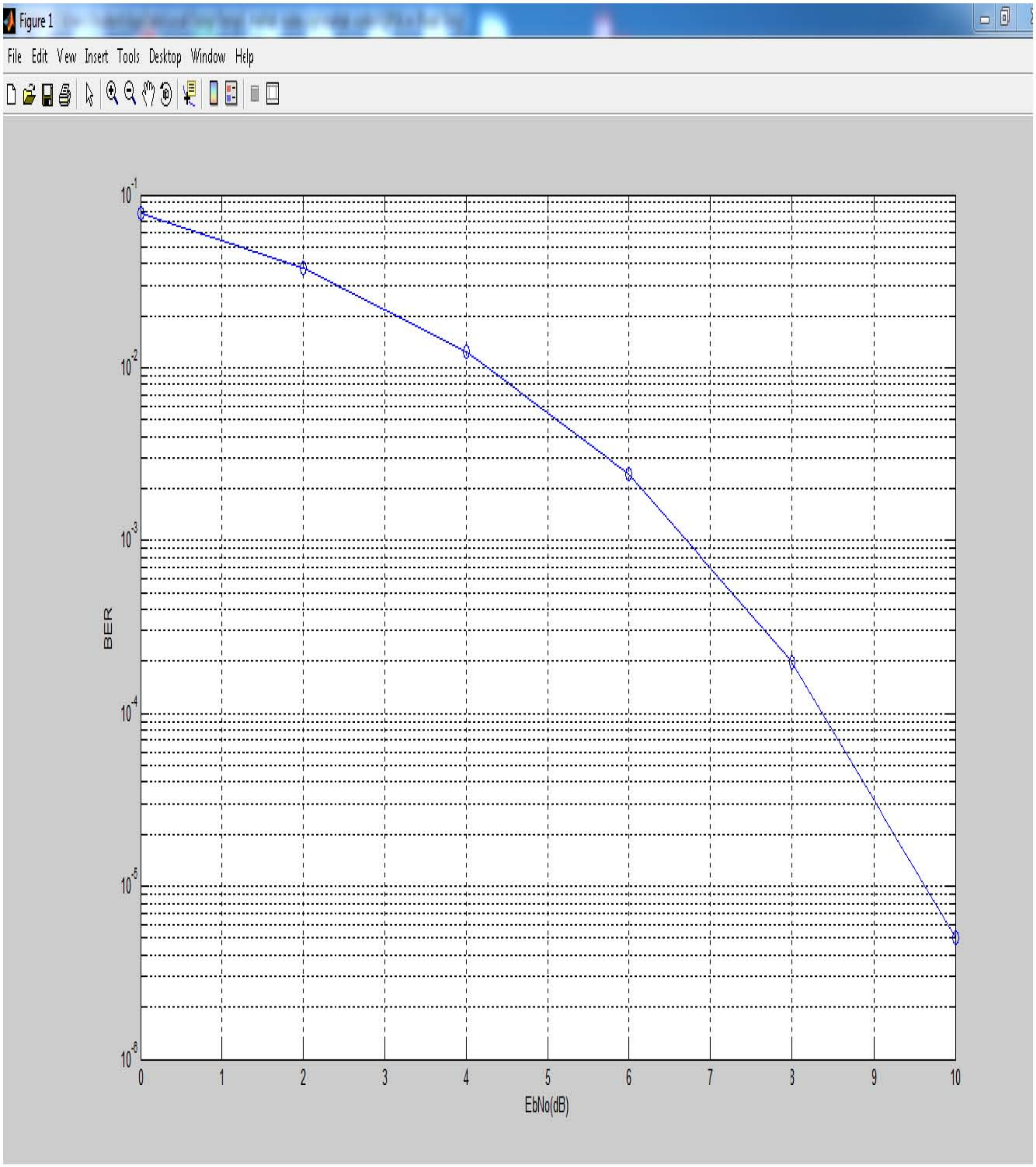


Figure 1
File Edit View Insert Tools Desktop Window Help
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
BER
0
1
2
3
4
5
6
7
8
9
10
EbNo(dB)

Chapter

8

Conclusions

In this thesis, we proposed model for ONU to SS network. Our aim is to improve the network condition by using multi-hopped network for Fi-Wi network. The advantages of relaying is coverage area of Base Station or Access Point can be extended, infrastructure-less networks can be maintained and aggregate path loss is lower than for direct link communication hence, transmit power is lower and/or data rates higher.

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