BER Analysis over Weibull-Gamma and Mixture-Gamma Fading Channels under SC Scheme in Presence of GGD Noise for Nano Communication System

A Thesis submitted in partial fulfillment of the requirement for the Award of the Degree of

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Submitted By

Akanksha Gupta

Roll No: 801761002

Under Supervision of

Dr. Ankush Kansal

Assistant Professor, ECED

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

ELECTRONICS AND COMMUNICATION ENGINEERING DEPARTMENT

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY

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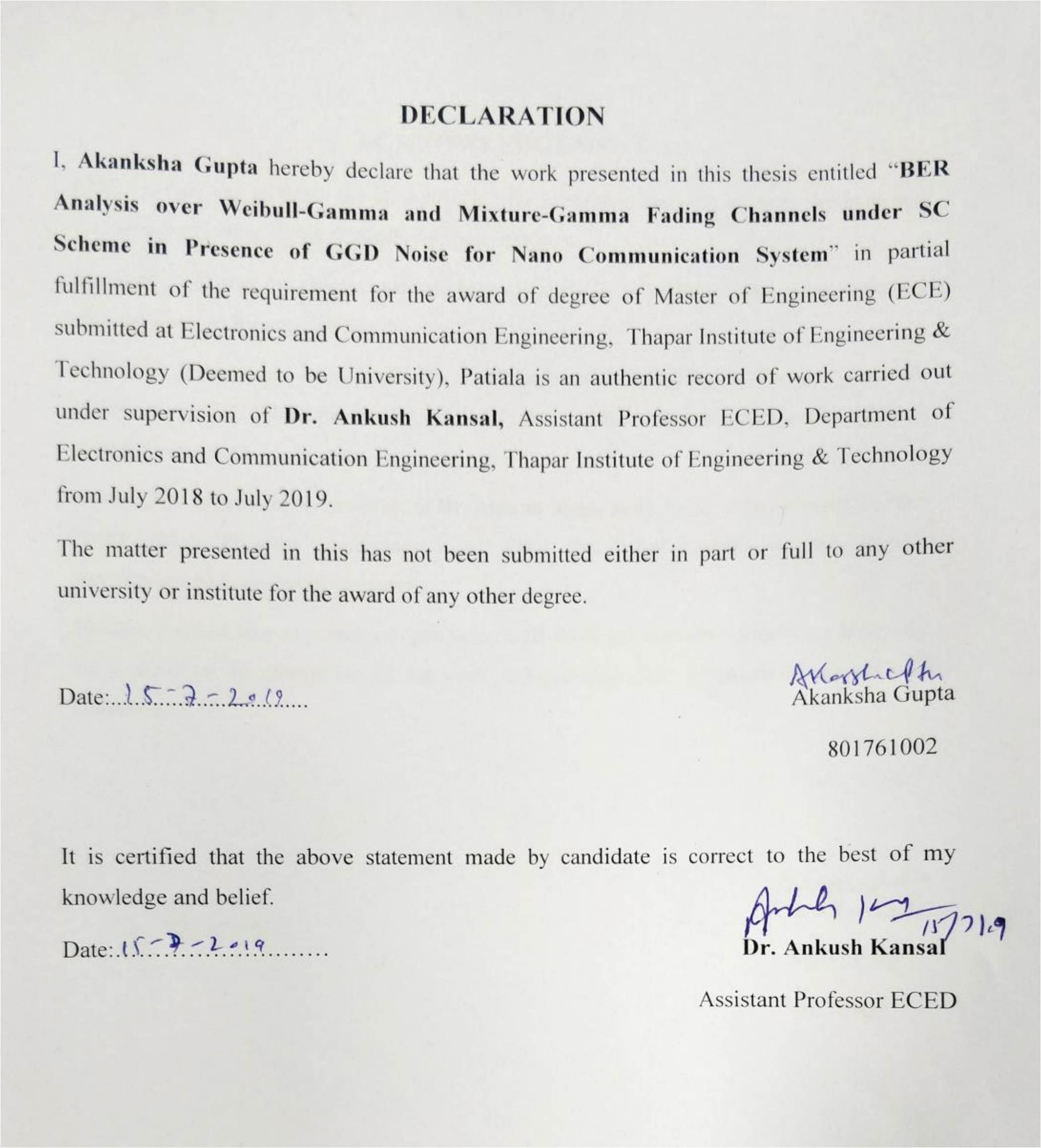


DECLARATION

I, **Akanksha Gupta** hereby declare that the work presented in this thesis entitled "**BER Analysis over Weibull-Gamma and Mixture-Gamma Fading Channels under SC Scheme in Presence of GGD Noise for Nano Communication System**" in partial fulfillment of the requirement for the award of degree of Master of Engineering (ECE) submitted at Electronics and Communication Engineering, Thapar Institute of Engineering & Technology (Deemed to be University), Patiala is an authentic record of work carried out under supervision of **Dr. Ankush Kansal,** Assistant Professor ECED, Department of Electronics and Communication Engineering, Thapar Institute of Engineering & Technology from July 2018 to July 2019.

The matter presented in this has not been submitted either in part or full to any other university or institute for the award of any other degree.

Date:..15-7-2019....

Akanksha Gupta

801761002

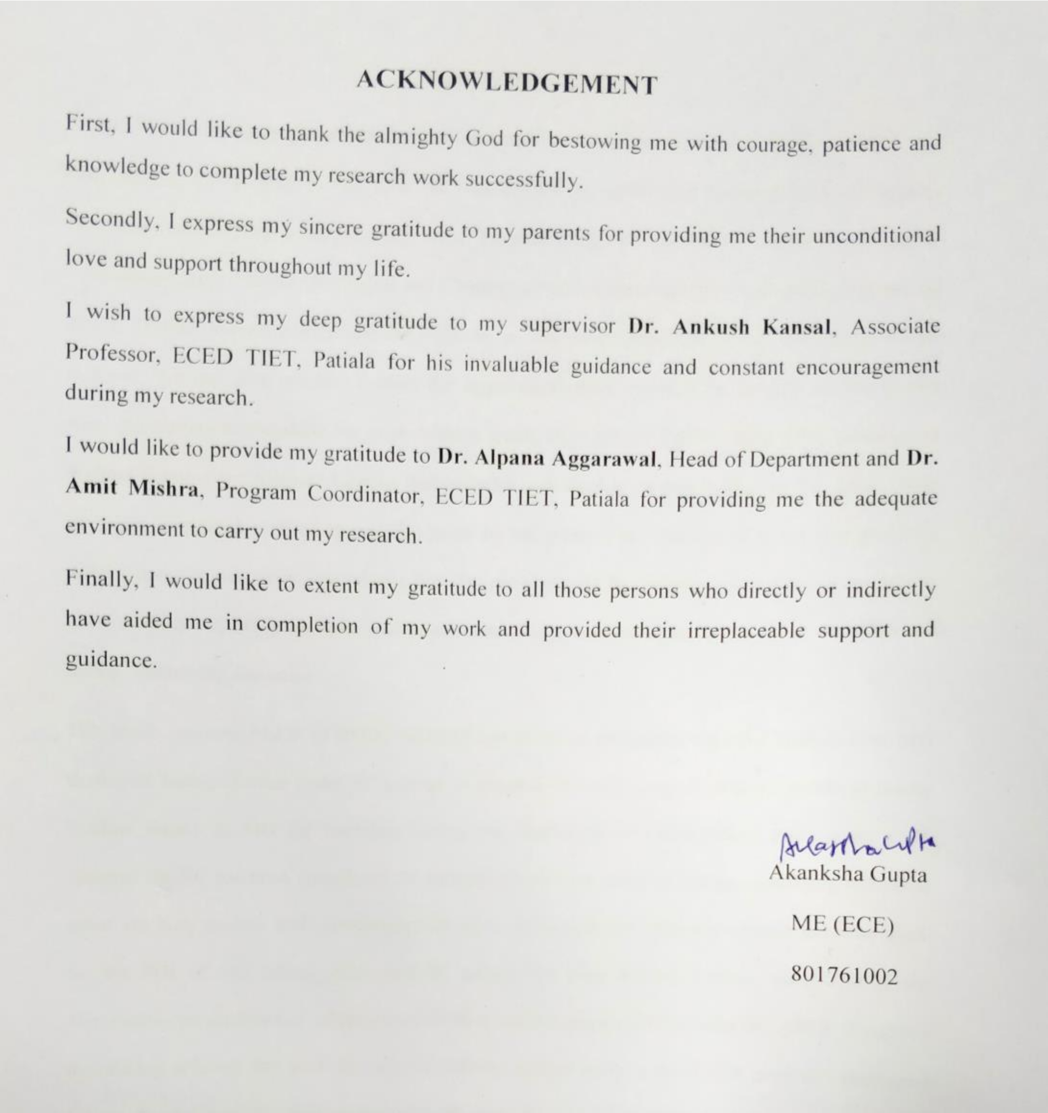
It is certified that the above statement made by candidate is correct to the best of my knowledge and belief.

Date:.15-7-2019........

15/7/19

Dr. Ankush Kansal

Assistant Professor ECED



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Akanksha Gupta

ME (ECE)

801761002

ABSTRACT

A completely new paradigm of communication known as Nano communication (NC) is making it’s place among the researchers very fast. NC has become an established research field and enables numerous new solutions in almost every field. Targeted Drug delivery system, Air pollution control, Food management, Nuclear Biological and Chemical (NBC) defense are few vital applications among others. Further, various researchers are working on real time application of NC around the world. However, for real time wireless system, the impairments which need to be focused are fading and noise. According to literature, the most suitable fading channels for EMNC under CM1 scenario are Weibull-Gamma and Mixture-Gamma that includes both shadowing and fading for NC. Also, GGD has been considered as most appropriate noise for NC under CM1 scenario. It is not only provided various noise models as its special case but also most suitable for operating over physical conditions of NC. Moreover, SC is an optimized impairments mitigation technique to overcome the effects of fading, shadowing and noise.

This thesis presents ABER of BPSK, M-PAM and M-QAM modulation schemes analysis over MG shadowed fading channel under SC scheme in presence of GGD noise. A suitable shadowed fading channel known as MG for modeling fading and shadowing of EMNC-based BAN under CM1 scenario for NC has been considered. To mitigate the adverse effect of fading, shadowing and noise occur via body posture and surrounding variations of the body, SC diversity scheme has been used. So, the PDF of MG fading under dual SC scheme has been derived. Further, using CEP of the aforementioned modulation schemes over GGD noise and proposed PDF under SC ABER of various modulation schemes has been derived. In addition, similar analysis for ABER over WG shadowed fading channel has also been presented with dual SC scheme at BPSK and M-PAM modulation scheme under same noise model.

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LIST OF ABBREVIATIONS

ABER	Average Bit Error Rate
AIGN	Additive Inverse White Gaussian Noise
AOF	Amount of Fading
ASEP	Average Symbol Error Probability
AWGGN	Additive white Generalized Gaussian Noise
AWGN	Additive White Gaussian Noise
BAN	Body area network
BPSK	Binary phase shift keying
CDF	Cumulative Distribution Function
CEP	Conditional Error Probability
CM	Channel Model
CSK	Concentration shift keying
DFF	Decision Feedback Filter
DNA	Deoxyribonucleic acid
ECDF	Empirical Cumulative Distribution Function
EGC	Equal-gain combining EGC
EGC	Electrocardiography
EM	Electromagnetic
EMNC	Electromagnetic Nano communication
GD	Gaussian Distribution
GGD	Generalized Gaussian Distribution
GSC	Generalized-selection combination
ICT	Information and Communication Technologies
ISI	Intersymbol Interference
KS	Kolmogorov - Smirnov
LD	Laplacian Distribution

LOS	Line of sight
MC	Molecular communication
MCRCTG	Modified Crossover Resistant Coding with Time Gap
MG	Mixture-Gamma
MGF	Moment Generating Function
MHP	Hermite pulse
MIMO	Multiple Input Multiple Output
MMSE	Minimum Mean Square Error
MNC	Molecular Nano Communication
MRC	Maximum-ratio combining
MTKS	Molecular Transition Shift Keying
NBC	Nuclear, Biological and Chemical
NBI	Narrowband interference
NC	Nano communication
N-L	Nakagami-lognormal
NLOS	No Line of sight
PAM	Pulse amplitude modulation
PDF	Probability Density Function
PL	Path loss
QAM	Quadrature amplitude modulation
R-L	Rayleigh-lognormal
SC	Selection combining
SNR	Signal to noise ratio
UD	Uniform Distribution
WG	Weibull-Gamma
W-L	Weibull-lognormal

CHAPTER 1

INTRODUCTION

In this era, demand from diagnosis hazardous diseases to control pollution or identified enemy target can be fulfilled with the new field of communication system called as Nano Communication (NC). The evolvement of such type of communication is based on a technology known as nanotechnology which allows handling entities at the atomic and molecular level [1]. By considering as a source of communication, atomic and molecular level techniques help researcher to gain their attention towards new emerging paradigm of communication. In recent years, this new paradigm which is known as Nano Communication (NC) found to very much helpful not only as a subject of research and development but almost every field of human aspects. Basically, NC has opened the door to enlarge the scope of potential applications in the field of environment, biomedical, military and industrial domain [2]. Here, Nano-machine which consists of nano scale components and considered as a most basic functional unit of nanotechnology used to perform some task at nano-level [3].

At Molecular scale, communication takes place through molecules and electromagnetic radio frequency waves are used to make communication possible at atomic scale. On the basis of above-mentioned characteristics Nano Communication has been classified as; Molecular Nano Communication (MNC) [3] and Electromagnetic Nano communication (EMNC) [4].For any wireless communication medium through which exchange of information take place is a crucial issue because of the randomness of medium is often high. After a search of appropriate way of communication, now time to focus on the medium through which molecules and atom make reliable communication is important. Various Impairments like fading, noise, interference are due to the medium between transmitter and receiver.

Presence of fading in any communication system reverts it into unreliable system. Noise adds unwanted signals into transmitted signals and converts the received signal into undesired signal. To deal with fading and noise is a difficult task than other impairment like interference in NC. Various composite fading distributions such as Nakagami-lognormal, Rayleigh-lognormal, Weibull-Gamma (WG) [5], Mixture-Gamma (MG) [11] etc. has been proposed in literature. Further, in the presence of impairments, performance analysis of different types of parameters like Bit Error Rate (BER), Spectral Efficiency, channel capacity etc. become a very difficult task. Like in any wireless communication, the performance analysis of above mentioned parameters are important in NC. Further, for modeling of noise in digital communication, a common channel known as AWGN is used. In NC, Additive White Gaussian Noise (AWGN) [8] and Additive Inverse White Gaussian Noise (AIGN) [9] used for modeling noise in EMNC and MNC. AIGN distribution is considered as a special case for Generalized Gaussian Distribution (GGD).Basically, for the measurement of noise information at wide range then GGD is an appropriate choice. Hence, GGD proves a most generic distribution in order to model noise in NC.

Diversity is a scheme to deal with the detrimental effects of fading. Various diversity scheme has been proposed in [10] such as Equal-gain combining (EGC), Generalized-selection combination (GSC), maximum-ratio combining (MRC) and Selection combining (SC). The scheme which gives an optimized result for the signal is SC. EGC has the problem with its gain and due to gain its SNR performance also affected. The problem in MRC is its structure complexity. Therefore, for handling the signal degradation problem SC is best fitted.

1.1 NANOTECHNOLOGY

A new technology called nanotechnology was searched for providing help in the development of the nano machines at scale range of 1 to 100 nm. These machines are able to take advantage of the specific characteristics of nano materials at this scale. The interconnection of nano-machines called nanonetworks is used to expand the capabilities of single nano scale device [1]. Advantage of Nano networks are that they are capable of performing specific task namely actuation, sensing, computation etc. Another benefit of such an interconnection is to permit the devices to cooperate and share information [13].

Due to nano-machines limited potential and its tiny size, conventional communication is not possible in nano science. To deal with this situation, different types of communication techniques such as Electromagnetic (EM), molecular, acoustics etc. are proposed in literature. Therefore, the best optimistic approach for nano machines in communication is EM and molecular techniques [15].The area for nanotechnology is naturally wide. It includes fields related with science which is much diverse as semiconductor physics, organic chemistry, surface science, molecular engineering, micro fabrication etc. [16].

Another area related with science where nanotechnology play a very vital role is industrial area. It provides tools for detecting and controlling the formation of bio films in various industrial areas. Bio-films are a combination of nano and micro-organism and are used for cleanliness of residual water which comes from manufacturing processes and waste organic [18]. The research area and applications in nanotechnology is quite diverse and have extension from traditional physics devices to purely modern approaches.

One nanometer (nm) can be defined as one billionth of meter. After comparison, the range for carbon-carbon bond lengths or molecules spacing between atoms is about 0.12-0.15 nm and diameter for DNA [19] which has double helix is around 2 nm. Traditionally, the nano scale range for nanotechnology is from 1 to 100 nm and definition for nanotechnology is used which is followed by the National Nanotechnology initiative in US. In nanotechnology, nano scale devices are made up of by either molecules or atoms with its lower limit is set by atoms.

Nanotechnology also enables the expansion of biological and chemical nano-sensors that have an unprecedented sensing accuracy. Interconnection of nano-sensors will be served as a savior against the biological and nuclear attack on nano scale [16]. Due to these aforementioned application of nanotechnology, makes it different from other devices which is presented as a miniaturized size of equivalent microscopic devices.

1.2 NANO COMMUNICATION

Use of nano machines for exchange of information secretly at atomic and molecular level called nano communication. Nano machines must be pre-implanted if nano communication is demanded in some applications related with health care, military etc. At the start of third world war, this new technology called nanotechnology was invented and used for inspection about the evolution of metal Gear Rex. Further, it served as a communicating device for the devices which has a scale range of nanometers and proves as an efficient problem solver for enhancing the nano machine characteristics. A single nano machine is not capable for making communication possible. So the set of interconnected nano machines called nano networks which accomplish certain task like sensing, storing etc. [20] used for making effective nano communication.

1.2.1 Nano communication classification:

To establish a link between transmitter to receiver for communication, nano communication can be categorized as MNC and EMNC where these two communication paradigm handle transmission either between molecules or between electromagnetic waves respectively.

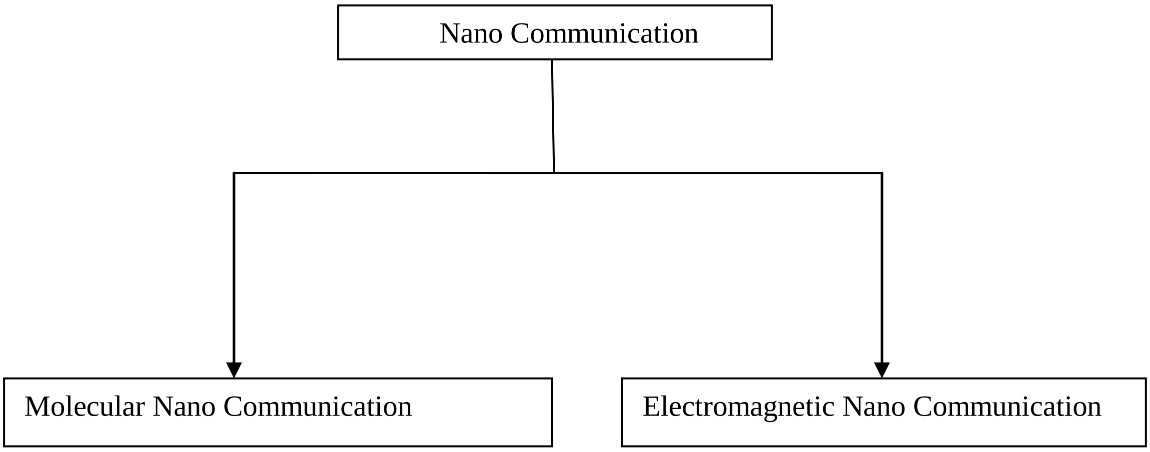

Figure 1.1 Basic classification of Nano communication

1.2.1.1 Molecular nano communication (MNC)

MNC is a new branch of wireless communication where molecules used are investigated as a solution to operate nano communication networks [18]. MNC presents as an interdisciplinary field which consists of bio, communication and nano technologies. The exchange of information in MNC takes place by means of molecules between transmitter and receiver nano machines. In other words, the use of molecules in MNC is to encode, propagate and decode information efficiently. Three different types of nano networks are presented in MC for giving a viable solution for molecule propagation through medium. In walk way nano network architecture, molecule propagation takes place by considering the carrier substances as a pre-defined path for connecting transmitter and receiver. In flow based nano network, propagation of molecules occurs through diffusion in fluidic medium whose flow is predictable and has guided turbulence. In diffusion based nano network architecture, molecule propagation takes place by spontaneous diffusion in fluidic medium [3]. Communication carrier in MC is chemical signals unlike already available communication systems whose communication carrier is optical and electronic signal.

In already existing communication systems, the information is encoded first such as voice, video, audio etc. and then this information is decoded or interpreted at the receiver. Further, in MC information is in molecule form and responsible for some reactions at the receiver, lastly sender transmits the chemical status which is recreated [21]. The energy requirement for communication in MNC is very less because of its bio-inspired nature. On the basis of range, MNC can be classified as Short range MNC [14] (nm) in which Calcium signaling and diffusion based communication model has been proposed. In Mid range MNC (um-cm) catalytic nanometers and flagellated bacterial have been proposed. Long range MNC (cm-m) defines all the capillaries, neurons, pollens and spores proposed models.

1.2.1.1.1 Basic components of MNC are:

a) Transmitter and receiver

b) Carrier

c) Medium

a) Transmitter and Receiver

In nano communication, nano machines used as a terminal device, so in MNC nano machines are used as a transmitter. Example of nano machines are nano robot, biomedical implant and modified living cells. Role of transmitter is to emit or capture the molecules which are a message signal in MNC. Transmitter activates the incoming or outgoing molecule flux and encodes the message signal in to various molecule concentration rates [20]. In transmitter, there is a boundary which defines the amount of molecule concentration inside the message signal.

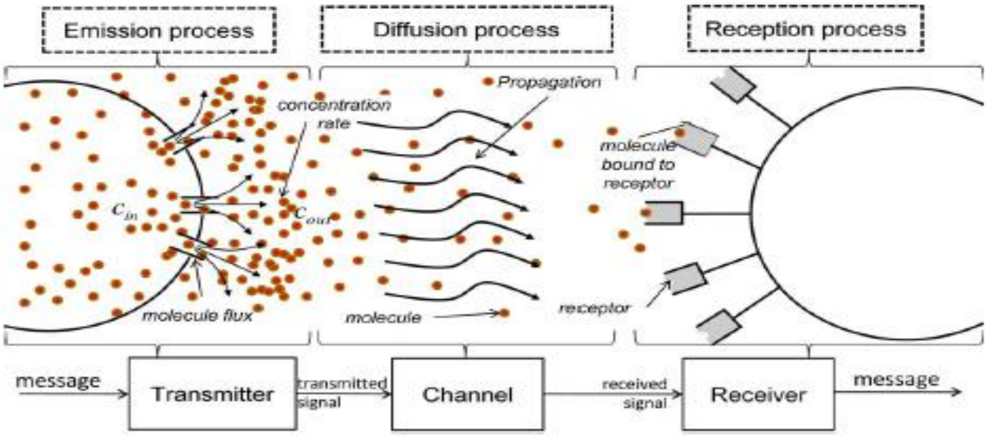

Figure 1.2 Communication model for Molecular Nano communication (MNC) [20]

At the receiver side also nano machines used as terminal device. Reception process has been accomplished at receiver and by use of various chemical receptors, receiver involves in emission and capturing of molecules from or into space [20]. Lastly the message is decoded from molecule concentration rate by the receiver.

b) Carrier

For exchanging the information from transmitter to receiver there is a need of carrier for carrying information. Here information is molecule and carrier which carries molecule is molecular motor. Capability of Molecular motor is to transfer molecular structure and chemo signals which contain information. Propagation capacity of molecules which have single information machine has also been enhanced by using molecular motor [1]. Condition for reliable communication is there is very less amount of external noise should be present. Molecular motor as a carrier fulfill this condition by preventing through noise

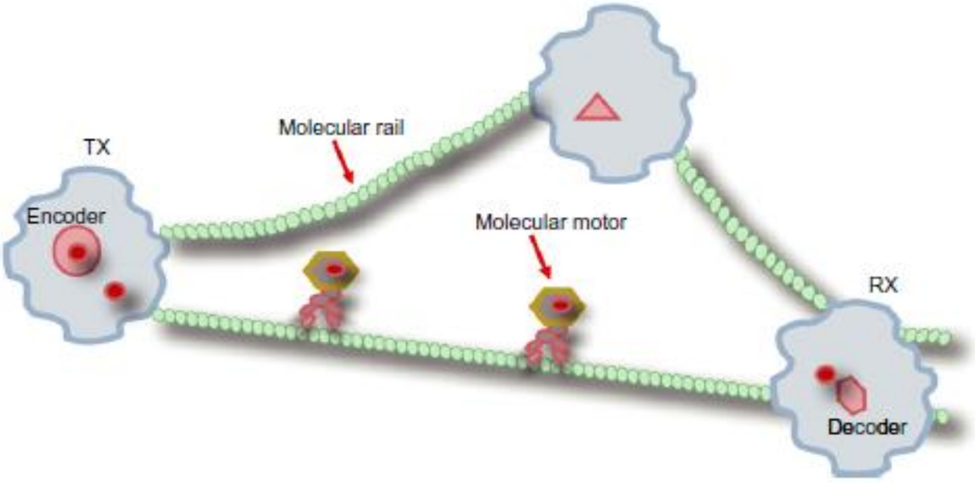

Figure 1.3 Molecular motor as carrier for MNC [1]

c) Medium

In any type of communication, medium plays a vital role for transferring information from transmitter to receiver. In other words, we can say that it is a weak link between transmitter and receiver for making reliable communication possible. In wireless communication, the unpredictability and randomness is quite high for medium. Medium in MNC is a path through which molecules is propagated and related with diffusion [20] when non-homogenous molecule concentration is occurred. At the time of diffusion process, Trend of homogenizing the concentration is followed by molecules which diffuse between transmitter and receiver. Lastly, medium transport the message signal as a function of time with distinctness in molecule concentration.

1.2.1.2 Electromagnetic nano communication (EMNC)

A communication between nano machines at nano scale through Electromagnetic waves (EM) presents a very optimistic approach in wireless communication. Further, EM waves are considered for communication in EMNC. EMNC is a combination of useful energy between nano technology and Electromagnetic (EM) Communication having various nano sensors with tetra hertz band [4]. In EMNC, emission, propagation and reception takes place through electromagnetic waves. In other words, EMNC can also be defined by considering the components whose base is novel nano material for transmission and reception of EM waves. The unique features of nano material are chosen on the basis of particular bandwidth of EM wave emission, its time lag or magnitude of emitted power [22].Minimal losses occur when these electromagnetic waves propagate through air or along with wires. EMNC have nano electronic devices as transmitter and receiver. However, for stable communication in EMNC, Set of nano electronic devices has been interconnected which creates a nano network.

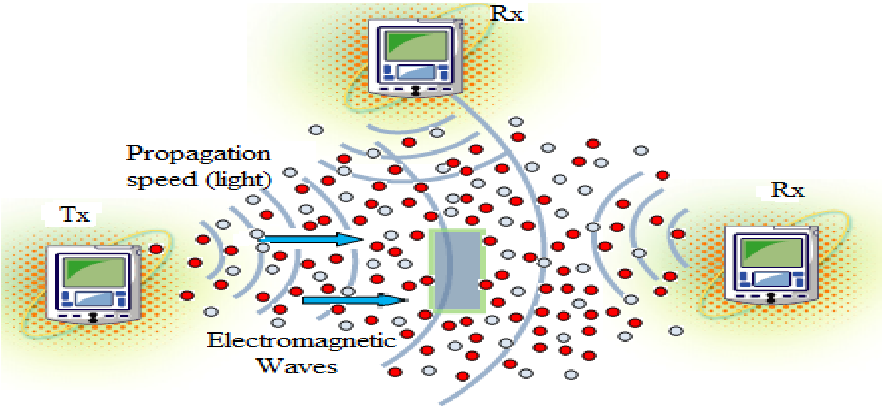

Figure 1.4 Architecture to define communication process in EMNC [1]

This nano network improves the capability of single nano electronic device to perform their already existing functionality for communication. This research is mainly focused on how to deal with all the issues related with healthcare, military, defense, food management etc. via communication [2].Till now all the communication was discussed for handle aforementioned issues had based on BAN but ‘On body’. So, the impactful solution for dealing with these issues has also been searched in the form of communication called nano communication which worked on ‘In body’ BAN. EMNC is one of the types of nano communication. For this purpose, EMNC under BAN is best fitted incase to deal with these issues. Another reason for considering EMNC in this work is fading. In communication, the most powerful factor which affects the whole process of communication is impairments. Fading is also an impairment and very difficult to handle comparison with other impairments in communication. With the help of BAN channel model under EMNC [6], we can model the fading and provide the improved result than previous one.

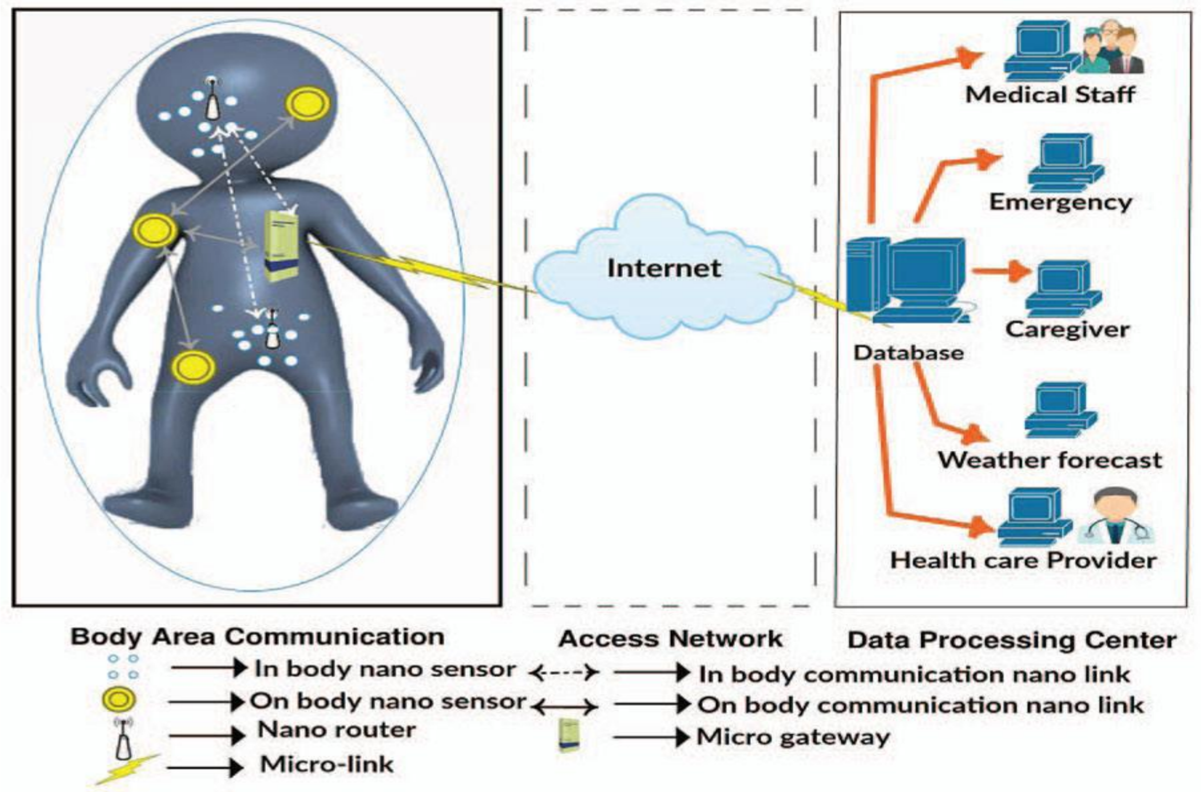

Figure 1.5 BAN model present a scenario of communication through EMNC for Healthcare [15]

Evolution of electronics nano scale components namely nano memories, nano antennas, logical circuitry, nano batteries etc. have done due to the advancement in molecular and carbon electronics. For high frequency, these electro-nano antennas have developed. Another name for nano machine is nano nodes which is simpler and smaller in size and used for performing simple task. By the use of nano-router, availability of computational resources is greater.

1.2.2 Comparison between EMNC and MNC

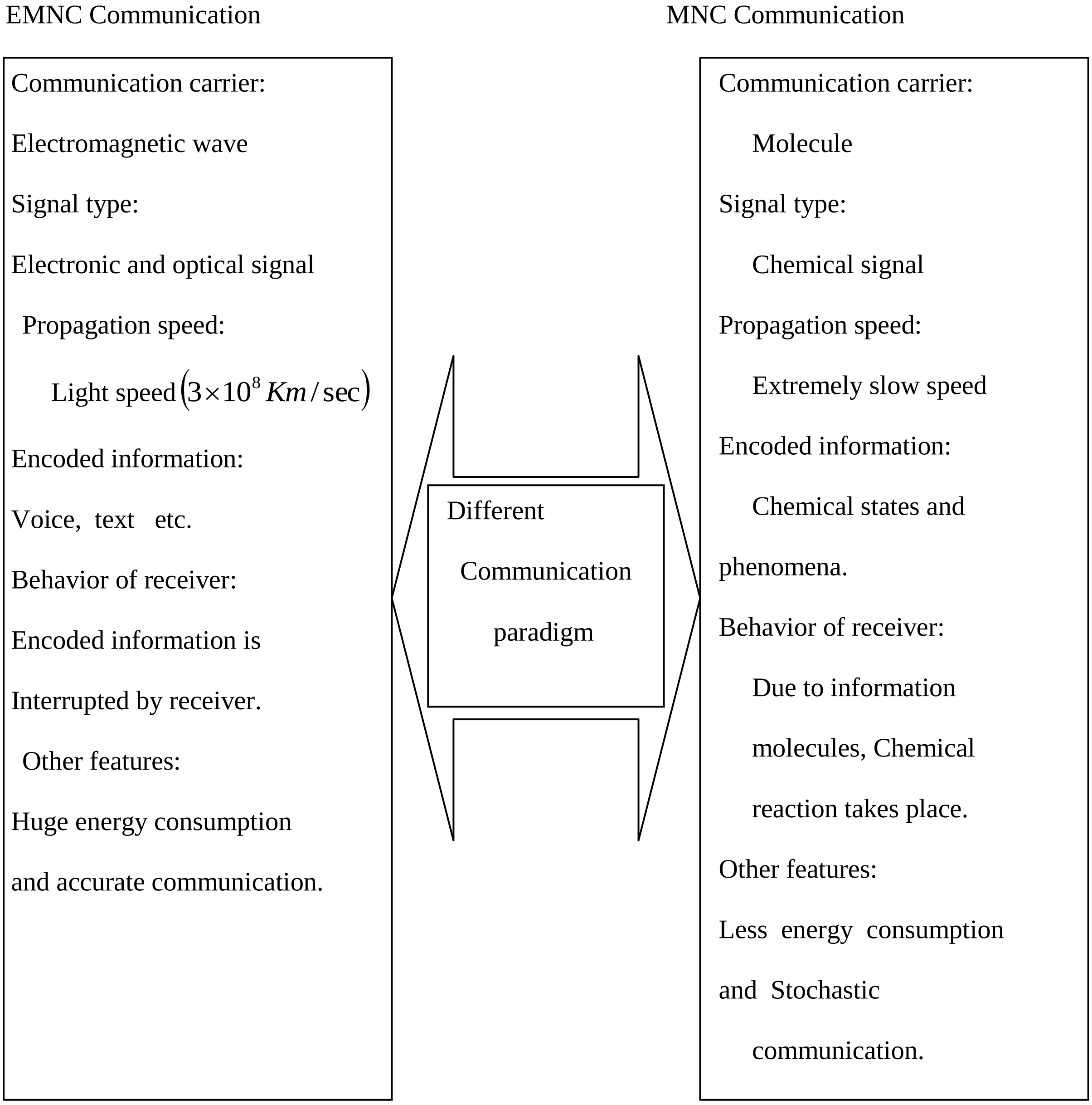

Figure 1.6 Comparison between EMNC and MNC [21]

1.3 FADING

Fading introduces distortion which is experienced by the carried modulated signal over propagation path. Fading is represented in the form of amplitude variation of power signal at the receiver. At the time of transmission, signal may go from different types of attenuations such as multipath fading, path loss etc. Multipath [23] refers to propagation phenomenon in which radio signal is reached at the receiving antenna with multiple paths. Fading is introduced due to multipath propagation and sometime considered as multipath induced fading when multiple copies of same signal are reached at the receiver. Shadowing is also an important factor which affects the communication process a lot.

Fading classification

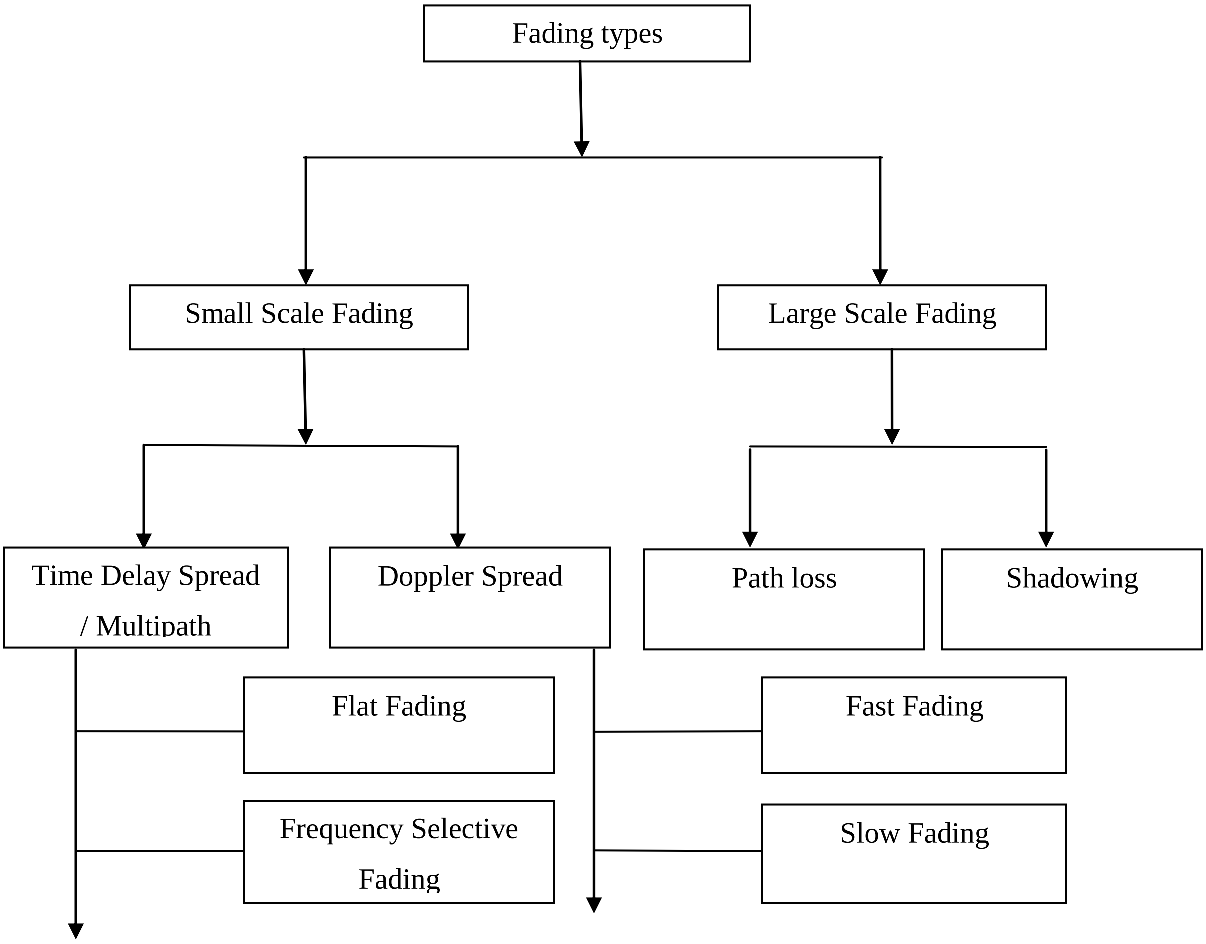

Figure 1.7Classification of fading [23]

1.3.1 Small scale fading [23]:

It refers to rapid fluctuation in the amplitude and phase of received power signal over a short distance.

Variation in instantaneous power of received signal is about 30 to 40dB when a movement in receiver is only a fraction of wavelength.

It includes two mechanisms such as behavior of channel according to time variation and signal dispersion [23] (signal spread according to time).

In mobile radio applications, shifting of signal between transmitter to receiver results variation in multipath propagation due to this channel behave as a time-variant.

1.3.1.1 Effects of fading due to time delay spread / multipath in small scale fading:

1.3.1.1.1 Flat fading

Flat fading introduce in received signal when the transmitted signal bandwidth is less than the bandwidth of the mobile radio channel [24] which has linear phase and constant gain.

Due to multipath, channel gain is fluctuated which caused the variation in the strength of received signal power with time.

In this fading, transmitted signal having reciprocal bandwidth is larger in amount than time delay spread of channel due to multipath.

Flat fading channel sometime considered as a narrow band channel because the transmitted bandwidth is smaller than channel bandwidth.

Deep fades occurs in this fading channel, so to attain a less BER at the time of deep fade [24] then 20 to 30 dB more transmitted power is required compared with when no fading channel is considered.

Instantaneous gain of this fading channel has amplitude distribution for mobile radio links and this distribution is presented in the form of Rayleigh distribution.

Condition for flat fading is [24]

$$B_s < B_c \tag{1.1}$$

$$T_s > \sigma_\tau \tag{1.2}$$

Where B_c represent the coherence bandwidth of the channel, B_s is the transmitted bandwidth of the signal, T_s is the reciprocal of bandwidth or symbol period and σ_τ is rms delay spread of the channel.

1.3.1.1.2 Frequency selective fading

Frequency selective fading is introduced on received power signal when the bandwidth of this fading channel is less than the transmitted bandwidth of signal.

Multipath delay spread is produced for channel impulse response due to its delay spread bandwidth is greater than the reciprocal transmitted bandwidth of the signal [25].

When above condition occur, multiple copies of the same transmitted signal is generated at the receiver in the attenuated and delayed form with respect to time, hence signal distortion is received.

Channel modeling of frequency selective fading is much more difficult than flat fading because separate modeling of each multipath signal is required and filter is also linear required.

Frequency selective fading is some time referred as wide band channel since the transmitted signal bandwidth is wider than channel response.

Condition for frequency selective fading is [24]:

$$B_s > B_c \tag{1.3}$$

$$T_s < \sigma_\tau \tag{1.4}$$

Above condition is presented for the selection of frequency selective fading.

1.3.1.2 Effects of fading due to Doppler spread in small scale fading

Depending how fastly the change is shown in the transmitted signal as compared with the variation in the channel, channel classification is defined as:

1.3.1.2.1 Fast fading

In fast fading, there is a very rapid change in channel impulse response with respect to symbol duration.

In this fading, channel’s coherence time is smaller than the transmitted signal symbol period.

Due to Doppler spread effect, frequency dispersion of the signal is caused hence and received signal is got distorted [24].

Fast fading deal with the channel which is varied due to motion and it is introduced only for date rates with low value.

Condition for fast fading [24]:

T_C Denotes coherence time of the channel and B_D represents the Doppler bandwidth.

$$T_s > T_C \tag{1.5}$$

$$B_s < B_D \tag{1.6}$$

1.3.1.2.2 Slow fading

Rate of change of channel impulse response is slower than transmitted signal in case of slow fading channel.

Channel in slow fading is assumed to be fixed [24] for one or more reciprocal bandwidth intervals.

Doppler spread for channel in frequency domain is smaller than the transmitted signal bandwidth.

Condition for slow fading is [24]:

$$T_s < T_C \tag{1.7}$$

$$B_s > B_D \tag{1.8}$$

1.3.2 Large scale fading

In large scale fading, the attenuation and path loss of received power signal is presented due to the movement of signal over long distance (100 m- Km).

In this fading, motion's speed describes the fadedness level of the signal when mobile signal is moved between transmitter to receiver.

Reason for occurrence of large fading [24] in signal is building height, terrain, vegetation etc.

Mainly predict the coverage area of the transmitted signal and availability of resources.

1.3.2.1 Path loss

Path loss defines the difference between transmitted power measured in dB and the effective received power and in other words path loss can also be presented as attenuation.

In path loss evaluation, antenna gain is may or may not be considered.

Formula for path loss with antenna gain:

$$PL(dB) = 10\log\frac{P_t}{P_r} \tag{1.9}$$

1.4 NOISE

Another important impairment out of various impairments in wireless communication is noise. To deal with noise is a difficult task in any communication. Noise is an unwanted signal which appears at the time of transmission which makes communication unfeasible. Removal of any impairment completely is not possible from the signal only possibility is reduction in their effect by using different techniques. Noise in nano communication can be modeled for either MNC or EMNC using Additive Inverse White Gaussian Noise (AIGN) [9] and Additive White Gaussian Noise (AWGN) [8]. AWGN is considered as a noise and when signal is transferred through channel then signal is affected by this AWGN noise. Basically, AWGN consists of uniform frequency spectrum of continuous type over specific frequency band. AWGN is best choice for fixed wireless channel with Line of Sight (LOS) and for fading channel its amplitude is flat[27].

AIGN is also an additive noise but the distribution is used in AIGN is inverse Gaussian (IG). This AIGN model was firstly introduced in [9] where capacity lower and upper bound was discussed with the constraint of average delay. However, there is another distribution for model the noise known as Generalized Gaussian Distribution (GGD). This distribution is applicable for modeling the noise in underwater communication. Random variables of GGD distribution is depending on the value of noise shaping parameter ‹ p ›. We can also defined GGD noise as a special case for the common types of noise. As ‘ p ’ = 1 then it is known as Laplacian noise and ‘ p ’ = 2 then it became a well known noise called Laplacian noise [28]. Till now, the modeling of noise in NC had been accomplished through AWGN and AIGN. Due to the applicability of GGD for aqua or under water scenario for measuring noise data over various fading channel conditions, it is also best choice for noise modeling in nano communication [29].

AIGN is a special case of GGD, so GGD also proves a more generalized model as AIGN to represent noise in nano communication. Analysis of Average Bit Error Rate (ABER) at different modulation techniques over GGD noise with composite fading model under dual SC has been discussed in this thesis. For this purpose Conditional Error Probability (CEP) of different modulation techniques under GGD consideration is required. CEP of BPSK under GGD or Additive white Generalized Gaussian Noise (AWGGN) channel has already been derived in [28-29]. In [30] also CEP is defined for M-PAM and M-QAM with AWGGN channel under generalized fading channels. The proposed expression of CEP either for BPSK or M-PAM or M-QAM all are represented in the generalized Gaussian Q-function or Marcum Q-function. This function is helpful for computing the ABER at different modulation techniques.

1.5 DIVERSITY

To mitigate the repercussion of multipath fading, a practical scheme known as diversity has been used for improving the system performance in wireless communication. Diversity scheme can be defined as a most effective technique when information is reached at the receiver as a sum of multiple version of same transmitted signal having independent fading paths [10]. Various types of most popular and important diversity scheme like Equal-gain combining (EGC),generalized-selection combination (GSC), maximum-ratio combining (MRC) [48] and selection combining (SC) has been proposed in literature. These types of different diversity techniques such as Nakagami-*m* fading channel, Rayleigh fading channel, Rician fading channel, etc. have already been discussed in various fading models [49-53].

There is also a one fading channel called Weibull fading model which is best fitted for measurements of experimental fading distribution, in case of both outdoor as well as indoor environment [54-56].Based on diversity, three different types of contributions have been proposed for handling the performance of receiver over Weibull fading [10]. In one, switched diversity receiver over Weibull fading was discussed. Another one includes the SC diversity technique with dual branch over Weibull fading. Further, third one measures the parameters like SNR of received signal and outage probability for N-branches of SC in Weibull fading channel. For any diversity technique, the result is observed like SNR, outage probability, BER etc. must be in closed form [50]. Diversity techniques for reception has been used on a large extent in fading channel for mitigating the effect of fading includes both mobile and fixed radio communication[51]. There is an increment in the demand for diversity when decorrelation between signals at mobile station is shown as the separation for antenna increases. Diversity combining is a technique which strengthens the signal strength following any random path to reach destination once transmitted from source. Diversity strategy for summing all the signals coming from different N-branches and N-branches for receiver is considered for obtaining the improved performance in case of non-selective and slows fading [52].

While transmitting the signal from transmitter to receiver we can only select the source and destination but we cannot guide the exact path which the signal should follow to reach the destination in most effective way and because there are infinite number of paths from a signal can flow there is difference between different signal strength[53].Thus, there exists a communication barrier between the source and destination while communicating and there is the situation for which we use the technique of diversity combining. This thesis proposed a PDF under dual SC for composite WG and MG fading channel for analysis of ABER over GGD noise using proposed PDF for EMNC based BAN for CM1 model. To the author’s best knowledge the model for analysis of ABER under dual SC for WG and MG over GGD noise for EMNC under CM1 for BAN in nano communication is not available in literature till date.

1.5.1 Different types of diversity schemes are

1.5.1.1 Equal-gain combining (EGC)

In diversity technique, signal is reached at the receiver with a combination of all version of transmitted signal. This combination in EGC is performed by applying the weight on each branch with same factor regardless of its signal amplitude. Further, signal co- phasing is also required for preventing the signal cancellation [53].The implementation of EGC is much simpler than MRC where attenuators and adaptive control amplifiers are not required also no need of channel amplitude estimation. However, the gain we observe in EGC is much less; hence the SNR performance is also worse than MRC.

1.5.1.2 Maximum Ratio Combining (MRC)

Different types of diversity schemes are known for combining the signal which is originated by multiple branch of transmitted signal. When each branch of signal is multiplied with a specific weight which is proportional to the amplitude of the signal then this technique is known as MRC [50]. Moreover, the amplification of strong signal has also accomplished by MRC and weak signal gets attenuated. The implementation of MRC is little bit complex than EGC.

1.5.1.3 Selection Combining (SC)

Selection combining is an optimum diversity technique in which each signal branch has some SNR value [57], so a single branch with highest SNR has chosen at the receiver for effective communication.

1.5.2 Advantage of using SC diversity scheme in this work with fading models

To diminish the detrimental effect of multipath fading and shadowing in EMNC based BAN under CM1 SC1, selection combining (SC) receivers have been considered, because SC is optimum diversity scheme than EGC and MRC.

The implementation of SC is least complex, since only one diversity branch is used on which all process is performed.

Gain in EGC is very small in amount while improvement in system performance is also negligible.

Complexity in MRC for receiver is large which is proportional to the signal branches; hence the transmission of information is possible in MRC [57] through only multipath fading.

In SC, receiver continuously monitors the SNR for both channels and if there is any fall down in SNR of connected branch so it switched on highest SNR branch for preventing the discontinuity in phase [56]. In MRC, we need to first co-phased the signal branches and provide weight to each branch to ensure that all the branches are co-phased for achieving a maximum diversity gain.

1.6 APPLICATIONS

The potential use of nano networks in a wide range of applications such as biomedical, industrial, military and environmental is represented by NC [1].

1.6.1 Industrial and consumer goods

In this field, nano networks provide help in the development of new material, quality control and manufacturing process.

1.6.1.1 Water and food quality control [62]

In this case, nano network is advantageous as nano sensors network used for detecting toxic components and small bacteria which affects the quality of product. Further, small size chemical and biological agents which installed in water supplies can also be identified by the use of advanced self-employed nano-sensor network.

1.6.2 Biomedical [64]

This field is applicable in various support system, drug delivery process, genetic engineering and health monitoring in medical area.

1.6.2.1 Drug delivery systems

These systems can be considered as regulating machines for delivering drugs in the affected area of the body by using nano actuator. Moreover, this drug delivery system is also helpfulin order to compensate the metabolism disease.

1.6.2.2 Immune support system

Basically, the immune support system provides protection of organism against diseases. The combination of the nano-machines with immune system can cause the nano-machine to perform in a coordinated way for recognizing and controlling the foreign and pathogen elements. The role of Nanomachines to detect and eliminate procedure is very crucial. They are able to identify tasks of localization and immediately take action against malicious agents and cells, like cancer cells, resulting to perform treatments in a less aggressive and invasive way.

1.7.3 Military

Nano networks play a very vital role in military field where demand for deployment of nano machines is at the higher level for battlefield monitoring and actuation. Moreover, setup is deployed in small areas that means inside human body for monitoring the soldier’s performance. Nuclear, Biological and Chemical (NBC) defense and nano fictionalized equipments are the part of the military field where these nano networks devices used for recognizing targeted areas fill of biological and chemical agents and equipments for the military.

CHAPTER 2

LITERATURE REVIEW

The nano network architecture of MNC and EMNC has been studied in last few years for NC. The work proposed in this new emerging field of communication provides diverse solution in various areas such as biomedical, military, food management, environmental etc. The type of Nano Communication has been considered in this thesis is EMNC-based BAN under CM1 scenario. The deployment of EMNC-based BAN for recognizing problems related with the aforementioned areas is very high. Previous Literatures in which EMNC based BAN used addressed the occurrence of fading and shadowing problem in CM1 scenario. Few literatures provide solution to deal with this fading problem. Therefore, this thesis has been focused on modeling the fading and noise occur in EMNC also use diversity for improvising the performance of communication system in nano communication.

I. F Akyildiz *et al.* [1] discussed the architectural aspects, future features and recent developments to understand the scenarios of nano-machines. Moreover, explanation and comparison between the components of nano-machines has also been highlighted for better understanding of nano networks. They also provides detailed explanation of short range and long range communication using nano networks and Information and Communication Technologies (ICT) has been considered as a key contributor for nano network evolution.

To investigate the process of molecular communication when nano scale devices are considered as a terminal device, a new molecular end to end physical model has been proposed by M.Pierobon *et al.* [3] where fluidic medium is considered. According to author, a very less no. of literatures addressed the analysis of diffusion communication through nano networks. Diffusion through molecules has also not been noticed in the previous literatures, so at the receiver side the reliability and accuracy for the physical model has been limited. Therefore, for overcoming all the problems Authors makes a model based on three modules namely transmitter, receiver and signal propagation. A specific process has been assigned to each module. Moreover, system performance has been analyzed in term of through put and noise by M.Pierobon *et al.*

Existing composite fading models for modeling fading and shadowing have computation and analytical difficulties. Therefore, a novel distribution called MG has been proposed by S. Atapattu *et al.* [11] for wireless SNR. Mixture Gamma (MG) distribution not only present the accuracy for composite fading models but for fading SNR also provide a versatile approximation [11]. Because of the similarity between Weibull distribution [5] and Nakagami, hence WG can be approximated as Nakagami. Both WG and MG represent Weibull distribution and Rayleigh is more complicated than Nakagami [5], therefore Nakagami-Lognormal (NL) can be used for approximation of WL and further

NL is a special case of MG distribution [11]. Also, (N ≥ 1) represent the components of gamma distributions.

Kamya Yekeh Yazdandoost *et al.* [6] describe about some task groups whose purpose is to develop a model for EMNC-based BAN. These models have been presented in the form of fading channels. A table has been discussed by the Authors who include differentiation of channel models on the basis of its suitable scenarios and its range of frequency. The primary concern of this paper is to define the three types of nodes which is inserted inside the human body. Kamya Yekeh Yazdandoost *et al.* [6] have also been described the antenna effect, electrical properties of body tissues, channel characterization based on its model type. Moreover, the effects of fading, shadowing, path loss have also been discussed**.**

Few techniques for long range communication on the basis of wireless and wired communication has been elaborated by L.P Giné *et al.* [7]. In wireless communication the preferable medium for the exchange of information is only fluidic medium such as blood, air, water etc. without any physical link. In order to transfer of information in wired communication, a physical link is required. Two Fick's law has also been described L.P Giné *et al.* where Fick's first law explains the concept of instantaneous emission and Fick's second law defines the continuous emission. The performance parameters namely energy consumption, signal speed, hardware implementation and reliability of the system also improved. For long range communication, modeling technique has been proposed on the basis of which technique offer better result under which circumstances.

In any type of communication another factor which gained researcher attention is its security. Without security our best technology for communication becomes useless. Security techniques of NC have been described by F. Dressler *et al*. [12] in which first investigates the availability of solution and if available then checks how well that solution can apply for NC. It offers the new solution called biochemical cryptographic which open a new door in the direction of research and also shows different improvements in NC. Moreover [12] also compares the similarities of the proposed solution with the existing solution and explains the drawbacks of the already available solution for the today's problem of security in NC.

For diminishing the effect of ISI, a new modulation technique called Zebra-Concentration shift keying (CSK) has been proposed by S. Pudasaini *et al*. [17]. Further, molecules efficiency proves very helpful for the ISI reduction and used to inhibit the messenger molecules. Comparison between proposed Zebra CSK and conventional CSK have shown through demodulation technique where authors observed that the error for symbol detection is lower for Zebra-CSK than existing CSK. Moreover, [17] has been considered time slotted molecular communication as pair of transmitter and receiver nano-machine.

For enabling the communication between nanomachines a new alternative communication paradigm from the nature of the nanoscale has been proposed by I.F Akyildiz *et al.* [18]. The capability and application of single devices is enhanced in term of its operation range and its complexity has also been discussed in this new communication paradigm. However, two communication alternatives of NC have been envisioned such as MNC and EMNC. Moreover, the propagation methods for the communication alternatives are also described.

Internet of nano-thing has been enabled with the evolution of nanomachines and their interconnection with macro and micro devices. The impact of this new emerging networking paradigm is shown in almost every field ranging from home land to health care to environmental security. A reference architecture related with this new paradigm has been introduced by I.F Akyildiz *et al.* [20] and also discussed the current research on electromagnetic nano networks. Moreover, Authors describe the basic requirement of nano network and nano devices for new solutions from information and communication society. However, discussion on the type of communication challenges come across the electromagnetic nano networks is also provided. It elaborates the modeling of channel, nano network protocols, information modulation and nano network design.

Similarly, a mathematical model has been proposed by S. Kadloor *et al.* [26] for nano devices where time slotted molecular communication has also been considered. The proposed mathematical model has been used to evaluate PDF of the released molecule at the propagation time. This model is also helpful for the analysis of maximum data rate. However, the assumption of molecule propagation is to be one dimensional. Moreover, receiver noise in this model is not discussed since it may not provide us a correct result. Further to mitigate the effect of ISI, P. Akhkandi *et.al*. [32] proposed a channel model for molecular communication system in which one or two types of molecules is considered. Comparison for experience error rate has also been shown between two types of channel models. Therefore, Zebra-Modified Crossover Resistant Coding with Time Gap(MCRCTG) which consists of two type of molecule provide less error rate than the channel model called MCRCTG which consists of one type of molecule.

To evaluate the Average Bit Error Rate (ABER), a new model which consists of BPSK modulation technique with composite flat fading channel over Additive Generalized Gaussian noise has been proposed by H.Soury *et al.* [28] for nano communication. However, the considered composite channel in this paper is Generalized-K fading. Moreover, a general closed form expression has been presented for extended generalized-K fading in term of Fox’s H function. The expressions for the analysis of ABER are also offered in term of generalized Quarcum function for other few fading case by using generalized-K fading expression. The most common type of GGD noise namely Laplacian and Gaussian has been implemented for the analysis of ABER. Authors observe the impact of fading parameter and GGD noise on probability of error.

Further, a model for calculating the average symbol error probability (ASEP) has been introduced by H.Soury *et al.* [30] with Square QAM and M-PAM modulation technique over generalized fading channel subject to GGD noise. A generic closed form expression for extended generalized-K fading in term of Fox's H function and bivariate fox H function has also given. Authors evaluate SEP on special case of extended generalized-K such as Rayleigh and Nakagami-m for M-QAM modulation technique over Laplacian and Gaussian noise of GGD. Impact of modulation over GGD noise with composite fading channel has been obtained in term of ASEP.

MMSE–OSIC detection has been implemented by K.Tiwari *et al.* [31] for enhancing the MIMO system performance with the reduction in error rates than traditional MMSE. By considering the composite fading channel known as Weibull-Gamma which shows effect of fading and shadowing, system performance analysis has been completed by the authors. Along with WG fading channel, Impact GGD noise on wireless scenario has also been highlighted in this paper. The performance analysis of ASEP has been presented by compare different noises of GGD distribution namely Laplacian and Gaussian on the basis of its amount of fading at M-QAM modulation technique. It shows that use of MMSE-OSIC with the consideration of WG fading at M-QAM modulation over GGD noise provides an improved result of system performance than conventional MMSE with less complexity of its structure

B. Tepekule *et al.* [33] said that the energy efficiency can be enhanced with the reduction of ISI. Hence for reduction Authors proposed two solutions, one is transmitter based called Molecular Transition Shift Keying (MTKS) as a modulation technique and other is transmitter based called DFF as a filtering technique. Comparison b/w DFF and MMSE also presented for analyzing error performance in term of bit error rate and observe that when energy efficiency is a primary concern then consideration of DFF becomes more beneficial. When the distance b/w transmitter and receiver are increased, it leads to decrement in received molecules and increment in propagation delay. To overcome this problem, decode and forward scheme has been introduced. In order to improve the system performance relay node consideration becomes more advantageous.

Communication capabilities such as maximum distance and capacity have been affected through this energy constraint. Moreover, the available models of energy mostly deployed for the battery powered machines since can't apply directly on micro and nano scale machines. Due to the limitations in previous literature related with energy, a new energy model has been proposed by S.M. Kuran *et al.* [35] for communication based on diffusion. Analysis of system performance has been accomplished with the development of channel model where information is evaluated on the probability of correct decoding. Two optimization methods have been discussed for channel data rate and capacity. Authors considered human insulin hormone as a transmitter and a messenger molecule and conclude that effect of distance between transmitter to receiver on achievable rate is very minor.

Further, L.S Meng *et al*. [36] present a model for molecular communication with sub-optimal and optimal receiver detection based on diffusion. The effect of channel memory has also been analyzed resulting from residual diffused molecule by the use of information theoretic approach. Authors also indicate that optimal detection can easily achieved through proposed sub-optimal detection scheme without the need of priori probability. Receiver designed guarantees that the communication based on diffusion can't be failed even in case of infinite channel memory. Binary information is transmitted in this system through on-off keying with the use of single molecule.

Based on isomers as messenger molecules, three new modulation techniques for molecular communication through diffusion have been proposed by R.N. Kim *et al.* [37]. However, the scenario which is used in this new model is it considered a single transmitter and a single receiver. These three techniques are concentration-based, molecular-ratio based and molecular type-based. Authors compare the proposed result based on isomers molecular type with the existing model where conventional insulin concept is considered. Hence conclusion of this comparison is that the achievable rate performance for proposed modulation techniques is higher than insulin concept based. These three novel modulations were proposed for the support of five bits per symbol. Different binary modulation techniques namely IMoSK, ICSK and IRSK have been considered for modulation.

First the review of molecular electronics has been done. Therefore, a novel propagation model for the study of electromagnetic nano communication in terahertz frequency band (0.1-10 THz) has been discussed by M. J. Jornet *et al.* [38] based on molecular absorption and radiative transfer theory. In this paper, the limitation of already existing EMNC models in term its speed, complexity and power consumption has been discussed. Authors elaborate the advantage and disadvantage of terahertz band with the help of proposed results. Moreover, one of the advantages of terahertz band in case of high channel capacity is provide high achievable data rates and also enable the modulation and encoding techniques for reliable communication.

As the recent development has been done related with nano-machines, the biggest challenge which we need to resolve is the control and co-ordination of these nano devices. Investigation of challenges and opportunities when BAN network is connected with nano devices has been discussed by F. Dressler *et al*. [39]. Various types of integrated solution as a design approach have been explored in this paper at the time of interconnection of In-body nano communication with BAN. Authors of this paper derive the architecture of this nano network and then discussed all the essential functionality for the gateway of the network architecture. Identification of performance analysis based on simulation and security issue has been considered as a important aspects in case of BAN-In body interconnection.

The importance of GGD family in the form of analytical properties has been elaborated by A. Dytso *et al.* [47] due to its flexible PDF parameters in term of moment, entropy, reyni entropy etc. Whole discussion is divided into four parts where first part help for properties analysis of CDF, absolute moments, Mellin transform and moments. Second part represents the decomposition of GG random variables in to product of different order of GG random variable whereas third part describes the properties of GG distribution in the form of characteristic function. Authors also elaborate the GG distribution applications in various noise channels. Extension of GGD application in other fields also presented such as image processing. By gaining again interest of communication with Weibull fading channel, the performance of dual SC diversity receiver over Weibull fading channel has been studied. The difficulty of mathematics in the derived equation has also been solved in this paper by providing exact closed form of PDF, CDF and SNR for moment's outputs. The important performance parameter such as AoF, SNR, outage probability etc. had also been obtained in closed form.

A moment based approach for the analysis of L- branch MRC and EGC receivers over non-identical Weibull fading channel has been presented by G. K. Karagiannidis *et al.* [48]. However, various performance parameters namely amount of fading (AoF), output SNR, Average Symbol Error Probability (ASEP), outage probabilities has been evaluated for the analysis of communication system by the author. This paper concludes that as the correlation between the diversity branches increases leads to increment in the outage probability and normalized SNR and represents deterioration in ASEP. In order to avoid the mathematical difficulties which occur due to the unattainable closed form expressions for the existing distribution, simple and novel distribution has been introduced by S. Atapattu *et al.* [61] to model the effects of both fading and shadowing. In this distribution which is known as mixture gamma distribution, SNR follow mixture of gamma distribution and provides all the performance parameter in simple form.

Kolmogorov - Smirnov (KS) criterion has been considered by Raffaele Di Bari *et al.* [59] for the estimation of the statistical distribution of channel parameters. J. Shaik *et al.* [60] compared Cumulative Distribution Function (CDF) of several distributions with the Empirical Cumulative Distribution Function (ECDF) namely Nakagami (NK), Lognormal (L), Rayleigh (R), Weibull (W), and Normal (N). KS criterion discussed the compatibility of the channel amplitudes with both Weibull and Lognormal distributions and also indicates this distribution with a pass rate of 91%. According to KS criterion the passing rate is more than 95% for the lognormal distribution in case of the chest-to-waist channel model.

A non-Gaussian statistical modeling of interference as a superposition of a large number of small effects has been explained by J.Ilow *et al.* [73] with terminals distributed in the plane/volume according to a Poisson point process. But, it uses multiple access communication systems without power control. K. Gulati *et al.* [74] said, interference statistics for finite and infinite- area interference region with and without a guard zone around the receiver is derived mathematically using a software toolbox for statistical modeling.

2.1 IDENTIFIED GAPS

After keen literature review following research gaps has been observed.

1. ABEP over suitable shadowed fading is proposed for nano communication system in literature but performance improvement by mitigating the impairments is missing [29].
2. In literature, ABER has been analyzed only over BPSK [28] for NC but no other modulation techniques such as M-PAM and M-QAM have been analyzed.
3. GGD noise over fading channel with modulation technique discussed but with diversity technique has also not been discussed yet [32].
4. Mixture-Gamma PDF, CDF, MGF has been proposed in [11] but PDF under dual SC has not been discussed.
5. Fading distributions such as, WG and MG can suitably model the fading and shadowing of nano communication [59] up to 98% fit to empirical data.
6. SC is an optimized impairments mitigation technique [57] to overcome the effects of fading, shadowing and noise.

2.2 RESEARCH OBJECTIVES

On the basis of aforesaid research gap following objective have been achieved in this thesis.

1. Study of various shadowed fading channels under dual SC diversity scheme over AWGGN noise.
2. To derive a closed form expressions of ABER for various modulation techniques over WG and MG shadowed fading channel under dual SC diversity scheme in presence of GGD noise.
3. Performance evaluation of closed form expressions derived in objective 2 with existing channel models for matrices like ABER, PDF and CEP etc.

2.3 METHODOLOGY

In this thesis work, the focus has been laid upon analyzing the performance of the nano communication system in the presence of fading and noise. However, CM1channel model which works for implant to implant (deep inside the human body) has been considered for EMNC-based BAN in NC. Further, for modeling fading and shadowing WG and MG shadowed fading models has considered with dual SC diversity technique to mitigate the impairments (fading, noise, shadowing) which has not been considered yet. Moreover, noise modeling has been performed with the consideration of AWGGN channel as a generalized noise model.

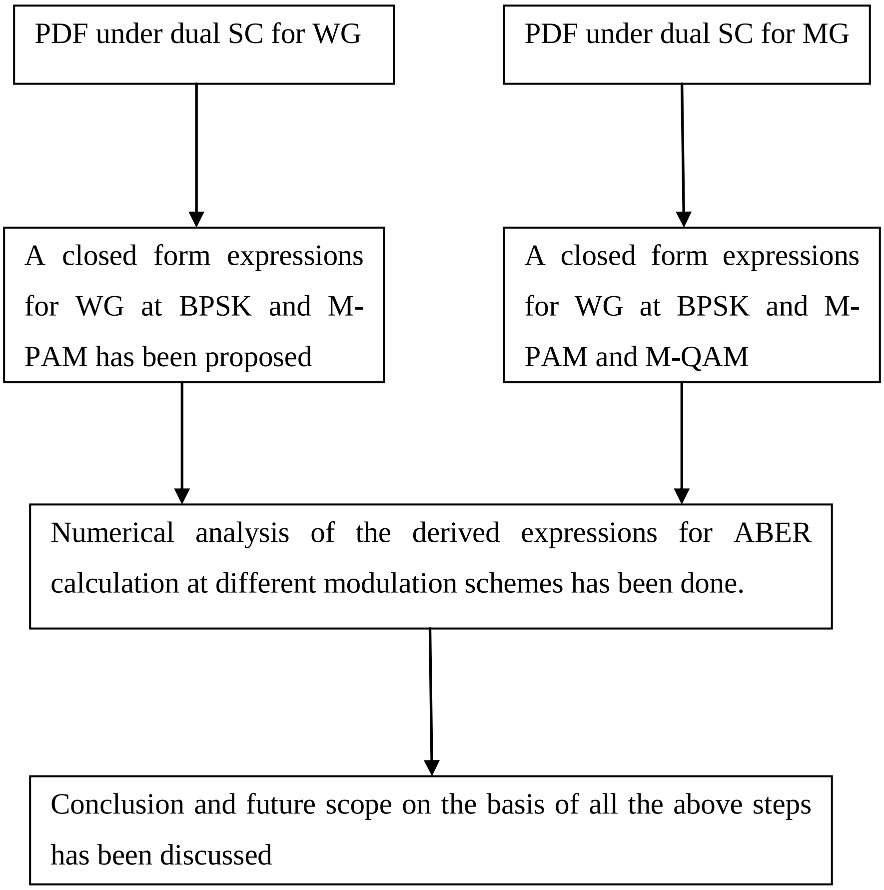

Figure: 2.1 Flow diagram for Methodology

CHAPTER 3

CHANNEL MODELING FOR NANO COMMUNICATION

3.1 INTRODUCTION

In wireless communication, the medium plays a crucial role and always be a weak link for communication. Through medium different impairments have been introduced like interference, noise and fading. Out of various impairments, the primary concern in the NC system is fading [21]. Different types of fading models for Body Area Network (BAN) based on EMNC have been proposed in the literature [6]. Experimentally, to evaluate the standard deviation and knowing about the blockage range for the human body, the shadowing effect of the human body has been considered while for NC, the shadowing model has been presenting [43]. Further, a distribution function that is proposed in the literature was compared with this model [43]. In addition, the effect of multipath fading in the aqua (underwater) medium is presented in [41]. In EMNC-based BAN, the channel model which works below the skin deep inside the human body tissues is known as channel model 1 (CM1) scenario. Fading and shadowing both are present in the CM1 scenario. In the CM1 scenario, the considerable reasons for fading are body postures, Reflection, diffraction, and energy absorption. In contrast, major reasons which cause shadowing in the CM1 scenario are surrounding variations and body parts movements. All stand-up/down postures except head and walking postures are considered as large movements in the human body.

Therefore, the Weibull distribution for this purpose shows a good match. Whereas all stand-up/down postures with head and rest postures of the human body are termed as small movements, hence the perfect model for this situation is log-normal distribution [42]. In conjunction, the compatible of signal amplitudes with both log-normal and Weibull distribution has been represented by Kolmogorov–Smirnov criterion with a pass rate of about 91%. Log-normal distribution when the chest-to-waist channel model is considered shows more than 95% pass rate. According to [42], the best choice for environments that is close to or below the skin of the human body in case of small-scale fading is log-normal distribution compared with Rician and Rayleigh distributions. Therefore, the channel in which Gamma distribution is used for approximation of log-normal distribution shadowing -known as Weibull-Gamma (WG) shadowed fading channel has been considered for the CM1 scenario [40]. For the representation of composite fading distribution, a more accurate and versatile approximated distribution called Mixture-Gamma (MG) distribution has proposed in [61]. Also, MG distribution has a special case which is Nakagami-lognormal distribution. Therefore, the suitable option to represent the CM1 scenario for EMNC-based BAN is MG shadowed fading channel.

Impairments like noise and interference come in the category of severely faded signals since it consists of severe effect. Noise effect on the performance analysis of the system in NC has been included in various numbers of literatures. The performance analysis of the NC system for the CM4 scenario in the presence of narrowband interference (NBI) has done in [44]. Also, reduction in NBI is achieved by choosing the Hermite pulse (MHP) [44] followed by conventional validation by transmitting magnetic resonance imaging and medical signals like electrocardiography. Till date, modeling of noise is accomplished as Additive Inverse Gaussian Noise (AIGN) [9] and Additive White Gaussian Noise (AWGN) [8] in MNC or EMNC of NC system. However, in [47] generalized Gaussian distribution (GGD) noise distribution is considered as the best fit for measuring noise data for an aqua(underwater) scenario over a large-scale ranging of physical channel conditions. So, for EMNC-based BAN under the CM1 scenario, the best-fitted model for noise is GGD [47]. In addition, to model noise in MNC [9] AIGN distribution is used. But GGD distribution has a special case which is also AIGN distribution. As a result, GGD noise distribution proves a more generalized model for representing the noise in the CM1 scenario of the NC system.

3.2 BODY AREA NETWORK (BAN)

In communication, step for the development of wireless BAN has been characterized by the propagation of electromagnetic waves from the device which is inserted either inside or on the human body. Basically, the communicating nodes which are used in BAN can be classified as [6]:

Implant node: means nodes are located deep inside the human body.

Surface node: means connecting nodes are placed on the surface of the human body.

External node: means communicating nodes are located not in contact with the human body.

3.2.1 Classification of channel model based on its location for BAN

3.2.1.1 In-body

Basically, In-body introduces communicating nodes inside the human body. SC1 and SC2 with CM1 and CM2 at 402-405 MHZ represent implant to implant condition. These implant to implant nodes are located in two places of the human body [6]. One is deep inside the human body tissue and another is the near-surface of the human body. In both the cases path loss and its exponent factor ‘n’ is different. SC3 scenario for CM2 at 402-405 MHZ can be approximated by using the combination of SC2 and SC6 (SC7).

3.2.1.2 On-body

On-body means connecting nodes are located either b/w surface of the body or b/w surface and external node. In the case of LOS when SC4 for CM3 at 13.5 MHz to 10.6 GHz has been considered then nodes are connecting b/w surfaces of the body. Further, when NLOS is the case, communicating nodes are located b/w surfaces but here scenario will be changed. Similarly, when SC6 for CM4 at 900 MHz to 10.6 [6] GHz is used, in that condition nodes are connecting b/w surface to an external node. The same connection has been done but at another scenario SC7 for CM4 at the same frequency.

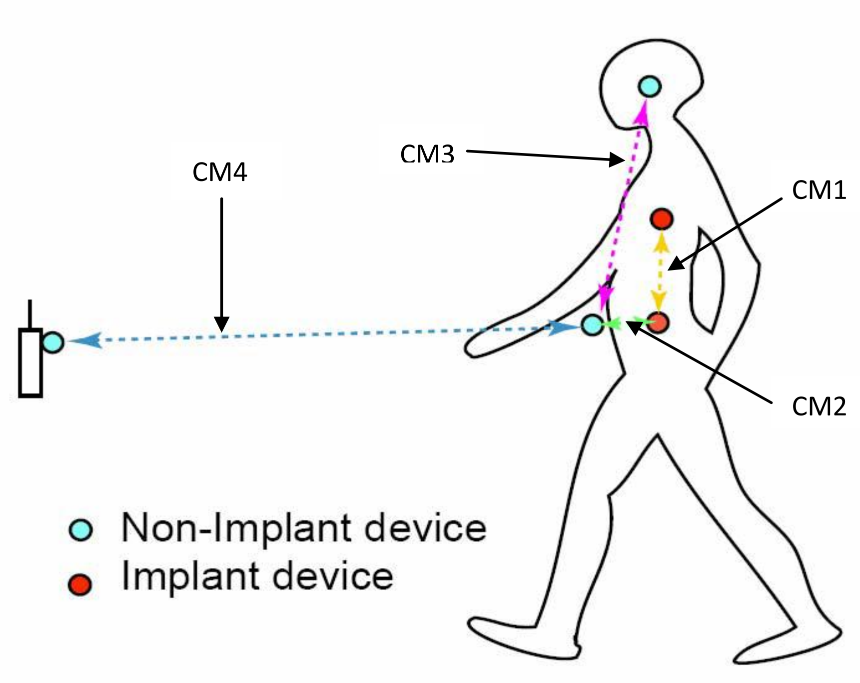

Figure: 3.1 Location of communicating link in BAN [6]

In figure 3.1 different channel model based on the location of its connecting nodes has been presented. These scenarios basically divided into two sections: In-body and On-body. In body consists of three Scenarios (SC1, SC2, and SC3) with two channel models (CM1 and CM2) at the same frequencies. On-body have rest four scenarios (SC4, SC5, SC6 and SC7) with two models (CM3 and CM4) at different frequencies.

3.2.2 Channel model description for EMNC-based BAN [6]

Scenario description has been presented on the basis of communicating node location (implant, body surface and external node) for channel models. In the table, SC denotes Scenario and CM denotes the Channel Model.

This table provides a description of all the scenarios for four channel models which can be considered as a modeling purpose for shadowing and fading in EMNC based BAN for Nano communication. Description is given on the basis of available frequency band and location of communicated node. Basically, four channel models can be considered for seven scenarios and these scenarios provide help for determining the correct location for communication in BAN.

Table: 3.1 Scenario list with its description

Scenario	Frequency Band	Channel Model	Description
SC1	402-405 MHz	CM1	Communicating node is located Implant to Implant.
SC2	402-405 MHz	CM2	Location of connecting nodes b/w Implant to the body surface.
SC3	402-405 MHz	CM2	Implant to external node connection.
SC4	13.5 MHz -10.6 GHz	CM3	In the case of LOS, the node is connected b/w body surface to body.
SC5	13.5 MHz -10.6 GHz	CM3	In the case of NLOS, the connection is b/w body surface to body.
SC6	900 MHz-10.6 GHz	CM4	In the case of LOS, the node is connected b/w body surface to external.
SC7	900 MHz-10.6 GHz	CM4	In the case of NLOS, the connection is b/w body surface to external.

3.3 COMPOSITE FADING CHANNELS MODEL FOR NANO COMMUNICATION

In literature, various fading models have been proposed for EMNC based BAN in NC. Basically, these models are considered for discussing the system performance for BAN devices. For NC, specifically in EMNC based BAN CM1 scenario is the best choice since it works deeply inside the human body tissues as an implant to implant node. In the CM1 scenario, shadowing and fading both occur together. Therefore, two composite fading models such as Weibull-Gamma (WG) [5] and Mixture-Gamma (MG) [11] have been considered for modeling the fading and shadowing simultaneously.

3.3.1 Composite Weibull-Gamma (WG) fading channel model

WG is a combination of Weibull and log-normal distribution. Weibull distribution in NC is used when large movements occur in the human body such as walking posture in case of right wrist; right upper arm and all stand up-down postures. Whereas log-normal distribution has been considered when small postures like all stand up-down posture with the head movement have occurred [42]. In literature, various composite distributions namely Rayleigh-lognormal is approximated as Rayleigh-Gamma, Nakagami-lognormal is approximated as Nakagami-Gamma respectively. Therefore, by following the same trend, Weibull-lognormal (W-L) can be approximated as Weibull-Gamma distribution.

3.3.1.1 Mathematical fading model for Weibull Gamma

In this proceeding section firstly we have presented approximated W-L distribution as WG distribution and then the composite PDF of WG distribution in terms of SNR has been presented.

If the distribution of random variable X is Log normal means X= e^Y can also be represented as Y=ln(X). Then its n^{th} moment is given as:

$$M_Y(n) = E(e^{Yn}) = E(X^n) = e^{n\mu+\frac{1}{2}n^2\sigma^2} \qquad (3.1)$$

Where $\mu = \psi(m) - \ln(m) + \ln(1-X_o) + \frac{X_o}{m}$ σ^2 = ψ (m) and expectation value is represented by E(.).

Also, mean and variance are defined by μ and σ^2 respectively.

By using the approximation method given in [45] and with mathematical manipulation Eqn. (1) can be written as:

$$M_Y(n) = \frac{\Gamma(y+m)}{\Gamma(m)} F_1(-y, m; -X_o) \qquad (3.2)$$

Where, F_1in Eqn. (2) is the hyper geometric function, Γ is the Gamma function and non-central chi-square distribution for the n^{th} moment is represented by Eqn. (2). It is worthy to mention here that, Gamma distribution have a special case in the form of chi-square distribution for positive integer k [46]

$$Gamma\left(x \middle| 2, \frac{k}{2}\right) = Chi - Sqr(x|k) = \frac{1}{2\Gamma\left(\frac{k}{2}\right)}\left(\frac{x}{2}\right)^{\frac{k}{2}-1} \exp -\left(\frac{x}{2}\right) \qquad (3.3)$$

Eqn. (3.2) and (3.3) proves that approximation of lognormal distribution is possible in Gamma distribution. Weibull distribution can be represented as:

$$f_W(\gamma) = \frac{\beta}{2a\bar{\gamma}}\left(\frac{\gamma}{a\bar{\gamma}}\right)^{\frac{\beta}{2}} \exp\left(\left(\frac{-\gamma}{a\bar{\gamma}}\right)^{\frac{\beta}{2}}\right) \qquad (3.4)$$

Where, average SNR is $\bar{\gamma}$ with $\bar{\gamma} = \Gamma\left(1+\frac{2}{\beta}\right)\Omega^{\frac{2}{\beta}} * \frac{E_s}{N_0}$ per symbol.

When multipath Weibull is superimposed on shadowing Gamma then WG distribution can be derived. Using Eqn. (3.3) and (3.4), we can represent WG PDF in terms of Meijer’s G function [69] as SNR form with the use of Weibull distribution given in Eqn. (3.4)

$$f_\gamma(\gamma)\Big| = \left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta/2} \frac{\beta k^{1/2}\lambda^{\alpha-(\beta+3)/2}}{2\Gamma(\alpha)(\sqrt{2\pi})^{\lambda+k-2}} \times [\gamma]^{\frac{\beta}{2}} \cdot \frac{\left[\alpha\Gamma\left(1+2/\beta\right)\right]\cdot\left(\lambda\gamma^{\lambda-1}\right)\cdot\gamma^{-1}}{\left(\bar{\gamma}\lambda\right)^{\lambda} k^k}$$

$$G_{2,k+\lambda+2}^{k+\lambda,2}\left(\frac{[\alpha\Gamma(1+2/\beta)\gamma]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^k}\middle|\begin{matrix}(0),(1-1/k)\\(b)_{k+\lambda},(-1/k),(1)\end{matrix}\right) + \left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta/2}\frac{\beta k^{1/2}\lambda^{\alpha-(\beta+3)/2}}{2\Gamma(\alpha)(\sqrt{2\pi})^{\lambda+k-2}}$$

$$\frac{\beta}{2}\left(\gamma^{(\beta/2-1)}\right)G_{1,k+\lambda+1}^{k+\lambda,1}\left(\frac{[\alpha\Gamma(1+2/\beta)\gamma]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^k}\middle|\begin{matrix}1-1/k\\b_{k+\lambda},-1/k\end{matrix}\right) \tag{3.5}$$

After simple mathematical manipulation, the aforementioned equation can be approximated as:

$$f_\gamma(\gamma)\Big| = k^{*}G_{2,k+\lambda+2}^{k+\lambda,2}\left(k_1(\gamma)^{\lambda}\middle|\begin{matrix}(0),(1-1/k)\\(b)_{k+\lambda},(-1/k),(1)\end{matrix}\right) + \frac{\beta}{2}\left(\gamma^{(\beta/2-1)}\right)G_{1,k+\lambda+1}^{k+\lambda,1}\left(k_1(\gamma)^{\lambda}\middle|\begin{matrix}1-1/k\\b_{k+\lambda},-1/k\end{matrix}\right) \tag{3.6}$$

Where, $k_1 = \frac{[\alpha\Gamma(1+2/\beta)]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^k}$ and $k^{*} = \left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta/2}\frac{\beta k^{1/2}\lambda^{\alpha-(\beta+3)/2}}{2\Gamma(\alpha)(\sqrt{2\pi})^{\lambda+k-2}}$ also

$b_{k+\lambda} = 1-\Delta(k,1), 1-\Delta\left(\lambda, 1-\alpha+\frac{\beta}{2}\right)$ and k , λ needed to be chosen according to such condition $\frac{k}{\lambda} = \frac{\beta}{2}$ to gives its value in integer form.

3.3.2 Composite Mixture-Gamma (MG) fading channel model

In wireless communication, fading effects at the time of propagation can be defined as macroscopic fading and microscopic fading. The large variation in the signal amplitude due to the effect of shadowing by trees, buildings and other objects is termed as Macroscopic fading. Microscopic fading is defined due to the effect of multipath and occurs in the indoor environment [11]. By using composite fading or shadowing distribution, modeling of microscopic and macroscopic fading can be completed together. Among these models, two models are most common which is Nakagami-lognormal (NL) and Rayleigh-lognormal (RL).

3.3.2.1 Mathematical fading model for Mixture-Gamma (MG)

Due to the occurrence of analytical and computational difficulties in composite models, [11] get motivated and proposed an accurate model for lognormal shadowing and also proposed a composite fading channel as Mixture-Gamma(MG) distribution in the form of SNR in wireless communication.

Followed by [11] PDF of MG can be written as:

$$f_\gamma(\gamma) = \sum_{i=1}^{N}\alpha_i\left(x^{\beta_i-1}\right)e^{-\zeta_i x}, \gamma \geq 0 \tag{3.7}$$

Where, N denotes no. of terms and special case for MG distribution is it reverts into Nakagami-m and Rayleigh fading by considering N=1.Parameters of Gamma components are defined as by α_i, β_i and ξ_i as its ith term.

3.4 CEP FOR DIFFERENT MODULATION SCHEMES OVER GGD NOISE

In any communication system, received signal (r) in term of transmitted signal t(s) with channel and system noise (n) can be written as:

$$r = h * t(s) + n \tag{3.8}$$

The noise (n) in Eqn. (3.7) is often defined by the distribution function. A most important fact about AIGN distribution is that it is used in MNC to model noise [9]. A most generalized model of noise is GGD where AIGN distribution is its special case. GGD is a generic model that means it represents different types of noise such as Laplacian distribution (LD) for $p = 1$, Gaussian distribution (GD) for p =2 and $p \rightarrow \infty$ represents Uniform distribution [46]. So, this section presents the already proposed CEP considering noise as GGD distribution for CM1 scenario at different modulation scheme.

3.4.1 CEP for BPSK under GGD noise

BPSK is a modulation technique in which variation in phase occurs either '1' or '0'. The CEP of BPSK signaling over GGD noise for evaluating ABER can be written as [29]

$$P_e(E/\gamma) = Q_\alpha\left(\sqrt{2\gamma}\right) = \frac{1}{2\Gamma(1/p)} G_{1,2}^{2,0}\left(\Lambda_0^p \left|\left(\sqrt{2\gamma}\right)\right|^p \middle| \begin{matrix} 1 \\ (0,1/p) \end{matrix} \right) \tag{3.9}$$

Here, shaping parameter of GGD noise is 'p' and $\wedge_0$ is normalized noise power in term of 'p'.

3.4.2 CEP for M-PAM under GGD noise

ABER for multi-level PAM in WG distribution has been derived. CEP for M-PAM signaling over AWGGN (GGD noise) is defined as [30],

$$P_e(E/\gamma) = Q_\alpha\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right) = 2 \cdot \left(1 - \frac{1}{M}\right) \cdot \frac{1}{2\Gamma(1/p)} G_{1,2}^{2,0}\left(\Lambda_0^p \left|\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)\right|^p \middle| \begin{matrix} 1 \\ (0,1/p) \end{matrix} \right) \tag{3.10}$$

Where $\Gamma(.)$ is a Gamma function, $\wedge_0 = \sqrt{\frac{\Gamma\left(\frac{3}{p}\right)}{\Gamma\left(\frac{1}{p}\right)}}$ is a normalized noise power.

3.4.3 CEP for M-QAM under GGD noise

CEP of M-QAM over the AWGGN channel (GGD noise) has been proposed in the literature. It is used in this section for evaluating the ABER and defined as [30]

$$P_e\left(E/\gamma\right)=4\left(1-\frac{1}{\sqrt{M}}\right)\cdot Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)-4\left(1-\frac{1}{\sqrt{M}}\right)^2\cdot Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)^2 \qquad (3.11)$$

Where, $Q_\alpha\left(\sqrt{\frac{3\cdot\gamma}{M-1}}\right)=\frac{1}{2\Gamma(1/p)}G_{1,2}^{2,0}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\sqrt{\frac{3}{M-1}}\right)\right)\right|^p\middle|\begin{matrix}1\\(0,1/p)\end{matrix}\right)$

3.4.4 Advantage of using CEP for different modulation techniques over GGD noise

For measuring the performance of any communication system, one of the most important metrics is error probability. However, CEP means Conditional error probability which is used for performance analysis of communication system in terms of ABER. At the time of performance evaluation as ABER, CEP formulation has advantage for providing benefits of its property in the form of error probability analysis. Generally, AWGN channel has been considered as a channel for noise but AWGN have limited properties. Therefore, a generic noise model known as GGD has been considered for modeling of noise. GGD overcome the problem of AWGN channel and also have some additional properties which make GGD general noise model.

At ‘p’= 1 in GGD noise model, noise is converted in to Laplacian noise. At ‘p’= 2 noise is converted in to Gaussian noise. CEP under GGD used in aqua (under water) scenario. CEP is different for different modulation techniques under GGD noise. This thesis considered three modulation techniques for analysis of ABER under GGD noise. The derivation for CEP under GGD noise has been performed using Generalized Q-function. Hence, for any modulation technique the formula for CEP under GGD noise is considered on the basis of Quarcum function. Single variable changes the CEP for different modulation.

CHAPTER 4

CLOSED FORM EXPRESSIONS OF BER FOR WEIBULL-GAMMA

4.1 INTRODUCTION

Composite fading distribution is an appropriate approach for nano communication when multipath and shadowing both occur simultaneously. It consists of distinct types of fading model namely Weibull, Nakagami-m, Rayleigh, Rician, mixture distributions, etc. Out of these several fadings, Weibull and mixture Gamma [10] distributions as a fading channel have been considered in this proposed work. This chapter mainly focused on mathematical modeling of Weibull-Gamma distribution or fading channel.

Weibull-Gamma (WG) [5] fading distribution has been proposed for providing a model when multipath is superimposed on shadowing. It also provides help in the occurrence of different types of environmental conditions. Weibull-gamma distribution has a pass rate of about 90% that gives fitness for nano communication in the case of CM1 scenario [6]. This type of fading is easier to understand and relatively newer than other fading. Weibull gamma fading channel is the best fit for both types of communication either indoor or outdoor.

Noise is the difficult impairment to handle; hence its modeling is also important in NC system. Primarily, AIGN and AWGN have been considered to model noise in MNC or EMNC. AWGN is a most basic channel for transmission but its applicability is limited so another type of distribution is required for modeling noise in nano communication. Therefore, due to the conversion of AIGN as a GGD special case, GGD is a best choice for modeling noise of NC in under water scenario [41]. At any physical channel condition, GGD distribution measures the noise value over wide range.

In any type of communication, diversity has been acknowledged as a very powerful technique for taking an action against the inimical effects of fading channel. Various types of diversity like EGC, MRC, SC, etc. [9] have already been proposed in the literature. Due to these limitations in MRC and EGC [48], SC is considered as an optimization technique which mitigates the effect of impairments. Because of the advantage of SC [57], dual SC is adopted in this work for modeling the fading in nano communication.

Modulation refers to the variation in the properties of carrier signal with respect to the modulating signal. Basically, at the time of transmission signal power is getting decreased as it traverses from transmitter to receiver. Thus, for boosting up the power of the carrier signal, modulation techniques are used. Various modulation techniques are present such as, BPSK, DPSK, M-PSK, M-PAM, QAM etc. out of these, BPSK and M-PAM has been considered for modulation in this chapter.

4.1.1 Statistical parameters of Weibull-Gamma fading channel

4.1.1.1 PDF

Probability density function is a function whose value can be interpreted at any given point within the sample area. In other words, PDF is used for determining the probability of random variable with a specific range of values. Thus, for BER analysis PDF plays a very vital role for analyzing the probability of error in the considered system.

4.1.1.2 Amount of fading

Due to movements of body parts, fading occur in CM1 scenario of EMNC based BAN in NC. Therefore, with the analysis of amount of fading, severity of the fading channel is analyzed.

In this chapter, section 4.2 represents mathematical analysis with the derived PDF under dual SC and proposed closed-form expressions for ABER under WG over GGD noise. Moreover, numerical analysis with results has been performed in section 4.3. Section 4.4 shows performance improvement table and section 4.5 discussed the summary of whole chapter.

4.2 MATHEMATICAL CHANNEL MODEL FOR WEIBULL GAMMA FADING CHANNEL DISTRIBUTION

In this section, composite fading channel WG has been considered for modeling fading and shadowing in EMNC-based BAN under CM1 SC1 in nano communication. However, Diversity schemes also a good solution for diminishing the consequences of fading. Further, noise can be modeled in EMNC through GGD noise model. Therefore, PDF under dual SC has been derived and closed form expression with proposed PDF for calculating ABER using CEP of different modulation techniques over GGD noise distribution has also been derived.

4.2.1 Proposed PDF of WG under dual SC diversity scheme

Let γ be a channel fading envelope following Weibull-gamma distribution with CDF is given by [5]:

$$F_\gamma(\gamma)=\left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta/2}\frac{\beta k^{1/2}\lambda^{\alpha-(\beta+3)/2}\gamma^{\beta/2}}{2\Gamma(\alpha)(\sqrt{2\pi})^{\lambda+k-2}}G_{1,k+\lambda+1}^{k+\lambda,1}\left(\left[\frac{[\alpha\Gamma(1+2/\beta)\gamma]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k}\right]\middle\| \begin{matrix}1-1/k\\ b_{k+\lambda},-1/k\end{matrix}\right) \tag{4.1}$$

Where α is the shadowing parameter, β is the distribution shaping parameter and $G(.)$ represents Meijer's G function [reference paper]. Average SNR $\bar{\gamma}$ is defined as $\bar{\gamma}=\Gamma\left(1+\frac{2}{\beta}\right)\cdot\Omega^{\frac{2}{\beta}}\cdot\frac{E_s}{N_O}$ where E_S is energy per symbol and one-sided power spectral density is denoted by N_0.

Probability Density Function (PDF) with γ as a signal envelope can be obtained by using the [46] formula given below as:

$$f_\gamma(\gamma)\Big| = \frac{\partial}{\partial\gamma}\left(F_\gamma(\gamma)\right) \tag{4.2}$$

$$\begin{aligned} f_\gamma(\gamma)\Big| = {} & \left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta/2} \frac{\beta k^{1/2}\lambda^{\alpha-(\beta+3)/2}}{2\Gamma(\alpha)(\sqrt{2\pi})^{\lambda+k-2}} \times [\gamma]^{\frac{\beta}{2}} \cdot \frac{\left[\alpha\Gamma\left(1+2/\beta\right)\right]\cdot\left(\lambda\gamma^{\lambda-1}\right)\cdot\gamma^{-1}}{\left(\bar{\gamma}\lambda\right)^{\lambda}k^{k}} \\ & G_{2,k+\lambda+2}^{k+\lambda,2}\left(\frac{[\alpha\Gamma(1+2/\beta)\gamma]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}\middle|\begin{matrix}(0),(1-1/k)\\(b)_{k+\lambda},(-1/k),(1)\end{matrix}\right) + \left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta/2} \frac{\beta k^{1/2}\lambda^{\alpha-(\beta+3)/2}}{2\Gamma(\alpha)(\sqrt{2\pi})^{\lambda+k-2}} \\ & \frac{\beta}{2}\left(\gamma^{(\beta/2-1)}\right)G_{1,k+\lambda+1}^{k+\lambda,1}\left(\frac{[\alpha\Gamma(1+2/\beta)\gamma]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}\middle|\begin{matrix}1-1/k\\b_{k+\lambda},-1/k\end{matrix}\right) \end{aligned} \tag{4.3}$$

Where $b_{k+\lambda} = 1-\Delta(k,1)\,1-\Delta\left(\lambda,1-\alpha+\frac{\beta}{2}\right)$, and k, λ needed to be chosen according to such condition $\frac{k}{\lambda}=\frac{\beta}{2}$ to gives its value in integer form.

PDF is an essential tool for calculating the BER and Selection Combining PDF can be defined as [57]

$$f_\gamma(\gamma)\Big|_{SC(WG)} = M\left[F_\gamma(\gamma)\right]^{M-1} f_\gamma(\gamma) \tag{4.4}$$

Where M represents the number of diversity branches, Here we use M=2 shows dual selection combining scheme

Substitute Eqn. (4.1) and (4.3) in Eqn. (4.4), we get

$$\begin{aligned} f_\gamma(\gamma)\Big|_{SC(WG)} = 2 & \left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta/2} \frac{\beta k^{1/2}\lambda^{\alpha-(\beta+3)/2}\gamma^{\beta/2}}{2\Gamma(\alpha)(\sqrt{2\pi})^{\lambda+k-2}} G_{1,k+\lambda+1}^{k+\lambda,1}\left(\left[\frac{[\alpha\Gamma(1+2/\beta)\gamma]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}\right]\middle|\begin{matrix}1-1/k\\b_{k+\lambda},-1/k\end{matrix}\right)\times \\ & \left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta/2} \frac{\beta k^{1/2}\lambda^{\alpha-(\beta+3)/2}}{2\Gamma(\alpha)(\sqrt{2\pi})^{\lambda+k-2}} \times [\gamma]^{\frac{\beta}{2}} \cdot \frac{\left[\alpha\Gamma\left(1+2/\beta\right)\right]\cdot\left(\lambda\gamma^{\lambda-1}\right)\cdot\gamma^{-1}}{\left(\bar{\gamma}\lambda\right)^{\lambda}k^{k}}\times \\ & G_{2,k+\lambda+2}^{k+\lambda,2}\left(\frac{[\alpha\Gamma(1+2/\beta)\gamma]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}\middle|\begin{matrix}(0),(1-1/k)\\(b)_{k+\lambda},(-1/k),(1)\end{matrix}\right) + \left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta/2} \frac{\beta k^{1/2}\lambda^{\alpha-(\beta+3)/2}}{2\Gamma(\alpha)(\sqrt{2\pi})^{\lambda+k-2}} \\ & \frac{\beta}{2}\left(\gamma^{(\beta/2-1)}\right)G_{1,k+\lambda+1}^{k+\lambda,1}\left(\frac{[\alpha\Gamma(1+2/\beta)\gamma]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}\middle|\begin{matrix}1-1/k\\b_{k+\lambda},-1/k\end{matrix}\right) \end{aligned} \tag{4.5}$$

After some mathematical manipulation, we get PDF under Dual Selection Combining Scheme for WG

$$
\begin{aligned}
f_{\gamma}(\gamma)\Big|_{SC(WG)} &= \Xi_1 \gamma^{(3\beta/2+\lambda-2)} G^{k+\lambda,1}_{1,k+\lambda+1}\left(\left[\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}\right]\middle|\begin{matrix}1-1/k\\ b_{k+\lambda},-1/k\end{matrix}\right)\\
&G^{k+\lambda,2}_{2,k+\lambda+2}\left(\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}\middle|\begin{matrix}(0),(1-1/k)\\ (b)_{k+\lambda},(-1/k),(1)\end{matrix}\right)\\
&+\Xi_2\left(\gamma^{(3\beta/2-1)}\right)G^{k+\lambda,1}_{1,k+\lambda+1}\left(\left[\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}\right]\middle|\begin{matrix}1-1/k\\ b_{k+\lambda},-1/k\end{matrix}\right)\\
&\cdot G^{k+\lambda,1}_{1,k+\lambda+1}\left(\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^{\lambda}}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}\middle|\begin{matrix}1-1/k\\ b_{k+\lambda},-1/k\end{matrix}\right)
\end{aligned}
\tag{4.6}
$$

Where,

$$
\Xi_1 = 2\left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta}\frac{\beta k\lambda^{2(\alpha-(\beta+3)/2)}}{4\Gamma^2(\alpha)(\sqrt{2\pi})^{2(\lambda+k-2)}}\frac{\left[\alpha\Gamma(1+2/\beta)\right](\lambda).}{(\bar{\gamma}\lambda)^{\lambda}k^{k}}
$$

$$
\Xi_2 = 2\left[\frac{\Gamma(1+2/\beta)}{\bar{\gamma}/\alpha}\right]^{\beta}\frac{\beta k\lambda^{2(\alpha-(\beta+3)/2)}}{4\Gamma^2(\alpha)(\sqrt{2\pi})^{2(\lambda+k-2)}}\frac{\beta}{2}
$$

4.2.1.1 Meijer's G function:

A well-known term called Meijer G function is a general function and used known functions as a specific case. Example Fox H functions. A general definition for Meijer G function is defined by [70]

$$
G^{m,n}_{p.q}\left(\begin{matrix}a_1........a_p\\ b_1........b_q\end{matrix}\middle| z\right)=\frac{1}{2\pi i}\int_L\frac{\prod_{j=1}^{m}\Gamma(b_j-s)\prod_{j=1}^{n}\Gamma(1-a_j+s)}{\prod_{j=m+1}^{q}\Gamma(1-b_j+s)\prod_{j=n+1}^{p}\Gamma(a_j-s)}z^s ds \tag{4.7}
$$

4.2.2 Closed Form Expressions of BER at different modulation technique over GGD noise under dual SC diversity scheme

In this section, a closed-form expression using the proposed PDF (4.4) under dual SC over GGD noise has been derived for evaluating the Average BER. BPSK and M-PAM modulation schemes have been used for calculating ABER. General expression to evaluating BER for any model is defined as [29]

$$
P_e(E)=\int_0^{\infty}P_e(E/\gamma)\cdot f_{\gamma}(\gamma)d\gamma \tag{4.8}
$$

Where $P_e(E/\gamma)$ represents the Conditional error probability (CEP) of modulation technique and $f_\gamma(\gamma)$ is the PDF of the SNR of the fading channel for which ABER is evaluated.

4.2.2.1 Closed form expression of BER for BPSK modulation technique under dual SC diversity scheme over GGD noise

BPSK is a modulation technique in which variation in phase occurs either ‘1' or ‘0'. The CEP of BPSK signaling over GGD noise for evaluating ABER can be written as [28]

$$P_e(E/\gamma) = Q_\alpha\left(\sqrt{2\gamma}\right) = \frac{1}{2\Gamma(1/p)} G_{1,2}^{2,0}\left(\Lambda_0^p \left| \left(\sqrt{2\gamma}\right)^p \right| \begin{matrix} 1 \\ (0,1/p) \end{matrix} \right) \tag{4.9}$$

Here, ‘p’ is a shaping parameter of GGD noise

Putting Eqn. (4.6) and (4.9) in Eqn. (4.8), we get

$$P_e(E)_{BPSK} = \int_0^\infty Q_\alpha\left(\sqrt{2\cdot\gamma}\right)\cdot f_\gamma(\gamma)_{SC(WG)}\,d\gamma \tag{4.10}$$

Now, we divide the above equation into two parts

$$P_e(E)_{BPSk} = P_{e1}(E) + P_{e2}(E) \tag{4.11}$$

$$P_{e1}(E) = \int_0^\infty \Xi_1 \gamma^{(3\beta/2+\lambda-2)} \cdot \frac{1}{2\Gamma(1/p)} \cdot G_{1,2}^{2,0}\left(\Lambda_0^p \left| \left(\sqrt{2\gamma}\right)^p \right| \begin{matrix} 1 \\ (0,1/p) \end{matrix} \right) \cdot G_{1,k+\lambda+1}^{k+\lambda,1}\left(\left[\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k} \right] \middle\| \begin{matrix} 1-1/k \\ b_{k+\lambda}, -1/k \end{matrix} \right)$$
$$G_{2,k+\lambda+2}^{k+\lambda,2}\left(\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k} \middle| \begin{matrix} (0),(1-1/k) \\ (b)_{k+\lambda},(-1/k),(1) \end{matrix} \right) d\gamma \tag{4.12}$$

$$P_{e2}(E) = \int_0^\infty \Xi_2 \left(\gamma^{(3\beta/2-1)}\right) \cdot \frac{1}{2\Gamma(1/p)} \cdot G_{1,2}^{2,0}\left(\Lambda_0^p \left| \left(\sqrt{2\gamma}\right)^p \right| \begin{matrix} 1 \\ (0,1/p) \end{matrix} \right) \cdot G_{1,k+\lambda+1}^{k+\lambda,1}\left(\left[\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k} \right] \middle\| \begin{matrix} 1-1/k \\ b_{k+\lambda}, -1/k \end{matrix} \right)$$
$$G_{1,k+\lambda+1}^{k+\lambda,1}\left(\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k} \middle| \begin{matrix} 1-1/k \\ b_{k+\lambda}, -1/k \end{matrix} \right) d\gamma \tag{4.13}$$

Meijer G Function is shown in Eqn. (4.12) and (4.13) but when an equation is represented with three Meijer G function having two different variables known as bivariate Meijer G function. A solution of bivariate Fox H function is given as [71]

$$\int_0^\infty x^{\lambda-1} H_{p,q}^{m,0}\left(ax \left| \begin{matrix} (a_i,\alpha_i)_{1,p} \\ (b_j,\beta_j)_{1,q} \end{matrix} \right. \right) \cdot H_{p_2,q_2}^{m_2,n_2}\left(\beta x^h \left| \begin{matrix} (c_i,r_i)_{1,p_2} \\ (d_j,\delta_j)_{1,q_2} \end{matrix} \right. \right) \cdot H_{p_3,q_3}^{m_3,n_3}\left(\delta x^k \left| \begin{matrix} (e_i,E_i)_{1,p_3} \\ (f_j,F_j)_{1,q_3} \end{matrix} \right. \right)$$

$$= a^{-\lambda} \cdot H_{p,q;p_2,q_2;p_3,q_3}^{0,m;m_2,n_2;m_3,n_3}\left(\begin{matrix} (1-b_j-\lambda\beta_j;h\beta_j,k\beta_j)_{1,q} \\ (1-a_i-\lambda\alpha_{i;}h\alpha_i,k\alpha_i)_{1,p} \\ (c_i,r_i)_{1,p_2} \\ (d_{j,}r\delta_j)_{1,q_2} \\ (e_i,E_i)_{1,p_3} \\ (f_j,F_j)_{1,q_3} \end{matrix} \left| \, \frac{\beta}{a^h}, \frac{\beta}{a^k} \right. \right) \tag{4.14}$$

Now after comparison of Eqn. (4.12) with Eqn. (4.14)

$a = \left(\bar{\gamma}\sqrt{2}\right)^p, \lambda = \frac{2}{p}\left(\frac{3\cdot\beta}{2}+\lambda-2\right), n=0, m=2, p=1, q=2$ and $m_2, n_2, p_2, q_2, m_3, n_3, p_3, q_3$ all values are depend on the value of k and λ. $\beta = \left[\frac{[\alpha\Gamma(1+2/\beta)]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k}\right]$, $h = 2\cdot\lambda$ and $k = 2\cdot\lambda$

Similarly, Eqn. (4.13) compare with Eqn. (4.11)

$\lambda = \frac{2}{p}\left(\frac{3\cdot\beta}{2}\right)$ and rest of the values for this solution is same as the above solution values

So, solution for Eqn. (4.12) is given below:

$$\left(\bar{\gamma}\sqrt{2}\right)^{-p\frac{2}{p}\left(\frac{3\cdot\beta}{2}+\lambda-2\right)} \cdot H_{p,q;p_2,q_2;p_3,q_3}^{0,m;m_2,n_2;m_3,n_3}\left(\begin{matrix} (1-b_j-\lambda\beta_j;h\beta_j,k\beta_j)_{1,q} \\ (1-a_i-\lambda\alpha_{i;}h\alpha_i,k\alpha_i)_{1,p} \\ (c_i,r_i)_{1,p_2} \\ (d_{j,}r\delta_j)_{1,q_2} \\ (e_i,E_i)_{1,p_3} \\ (f_j,F_j)_{1,q_3} \end{matrix} \left| \, \frac{\beta}{\left(\bar{\gamma}\sqrt{2}\right)^{p\cdot\lambda}}, \frac{\beta}{\left(\bar{\gamma}\sqrt{2}\right)^{p\cdot\lambda}} \right. \right) \tag{4.15}$$

Also solution for Eqn. (4.13) is given below:

$$\left(\bar{\gamma}\sqrt{2}\right)^{-p\frac{2}{p}\left(\left(\frac{3\cdot\beta}{2}\right)\right)}\cdot H^{0,m;m_2,n_2;m_3,n_3}_{p,q;p_2,q_2;p_3,q_3}\left(\begin{matrix}\left(1-b_j-\lambda\beta_j;h\beta_j,k\beta_j\right)_{1,q}\\ \left(1-a_i-\lambda\alpha_{i;}h\alpha_i,k\alpha_i\right)_{1,p}\\ \left(c_i,r_i\right)_{1,p_2}\\ \left(d_{j,}r\delta_j\right)_{1,q_2}\\ \left(e_i,E_i\right)_{1,p_3}\\ \left(f_j,F_j\right)_{1,q_3}\end{matrix}\middle|\frac{\beta}{\left(\bar{\gamma}\sqrt{2}\right)^{p\cdot\lambda}},\frac{\beta}{\left(\bar{\gamma}\sqrt{2}\right)^{p\cdot\lambda}}\right) \tag{4.16}$$

The solution is given in (4.14) is in the form of bivariate Fox H function, conversion from Fox H function into Meijer G has been done using its transformation property which can be written as [71]

$$H^{m,n}_{p,q}\left[\begin{matrix}z\middle|(a_1,C)(a_2,C).......(a_p,C)\\ (b_2,C)(a_2,C).......(b_p,C)\end{matrix}\right]=\frac{1}{C}G^{m,n}_{p,q}\left(\begin{matrix}a_1,...........a_p\\ \\ b_1,...........a_q\end{matrix}\middle|z^{\frac{1}{C}}\right) \tag{4.17}$$

Where ‘C' is considered as 1.

Definition for equation given in (4.14) can be written as [71]

$$H^{0,m;m_2,n_2;m_3,n_3}_{p,q;p_2,q_2;p_3,q_3}\left(\begin{matrix}\left(1-b_j-\lambda\beta_j;h\beta_j,k\beta_j\right)_{1,q}\\ \left(1-a_i-\lambda\alpha_{i;}h\alpha_i,k\alpha_i\right)_{1,p}\\ \left(c_i,r_i\right)_{1,p_2}\\ \left(d_{j,}r\delta_j\right)_{1,q_2}\\ \left(e_i,E_i\right)_{1,p_3}\\ \left(f_j,F_j\right)_{1,q_3}\end{matrix}\middle|x,y\right)=\left(\frac{1}{2\pi i}\right)^2\int_{L1}\int_{L2}\phi(s,t)\theta_1(s)\theta_2(t)\cdot x^s\cdot y^t ds\cdot dt$$

(4.18)

Where, $\phi(s,t)$, $\theta_1(s)$ and $\theta_2(t)$values are given below:

$$\phi(s,t)=\frac{\prod_{j=1}^{n_1}\Gamma\left(1-a_j+\alpha_j s+A_J t\right)}{\prod_{j=1}^{q_1}\Gamma\left(1-b_j+\beta_j s+B_J t\right)\prod_{j=n_1+1}^{p_1}\Gamma\left(a_j-\alpha_j s-A_J t\right)} \tag{4.19}$$

$$\theta_1(s)=\frac{\prod_{j=1}^{m_2}\Gamma\left(d_j-\delta_j s\right)\cdot\prod_{j=1}^{n_2}\Gamma\left(1-c_j+\gamma_j s\right)}{\prod_{j=m_2+1}^{q_2}\Gamma\left(1-d_j+\delta_j s\right)\cdot\prod_{j=n_2+1}^{p_2}\Gamma\left(c_j-\gamma_j s\right)} \tag{4.20}$$

$$\theta_2(t)=\frac{\prod_{j=1}^{m_3}\Gamma\left(f_j-F_jt\right)\cdot\prod_{j=1}^{n_3}\Gamma\left(1-e_j+E_jt\right)}{\prod_{j=m_3+1}^{q_3}\Gamma\left(1-f_j+F_jt\right)\cdot\prod_{j=n_3+1}^{p_2}\Gamma\left(e_j-E_jt\right)} \tag{4.21}$$

Compare Eqn. (4.18) with Eqn. (4.15) and (4.16) we get,

$$H^{0,m;m_2,n_2;m_3,n_3}_{p,q;p_2,q_2;p_3,q_3}\left(\begin{matrix}\left(1-b_j-\lambda\beta_j;h\beta_j,k\beta_j\right)_{1,q}\\ \left(1-a_i-\lambda\alpha_{i;}h\alpha_i,k\alpha_i\right)_{1,p}\\ \left(c_i,r_i\right)_{1,p_2}\\ \left(d_{j,}r\delta_j\right)_{1,q_2}\\ \left(e_i,E_i\right)_{1,p_3}\\ \left(f_j,F_j\right)_{1,q_3}\end{matrix}\middle|\frac{\beta}{\left(\bar{\gamma}\sqrt{2}\right)^{p\cdot\lambda}},\frac{\beta}{\left(\bar{\gamma}\sqrt{2}\right)^{p\cdot\lambda}}\right)$$

$$=\left(\frac{1}{2\pi i}\right)^2\int\limits_{L1}\int\limits_{L2}\phi(s,t)\theta_1(s)\theta_2(t)\left(\frac{\beta}{\left(\bar{\gamma}\sqrt{2}\right)^{p\cdot\lambda}}\right)^s\left(\frac{\beta}{\left(\bar{\gamma}\sqrt{2}\right)^{p\cdot\lambda}}\right)^t ds\cdot dt \tag{4.22}$$

After putting values of Eqn. (4.19), (4.20) and (4.21) in Eqn. (4.20), then Eqn. (4.19) is substituted into Eqn. (4.12) and (4.13) to make a complete BER equation given in Eqn. (4.11). This is a solution of bivariate Meijer-G function and no built in function is available for bivariate Meijer-G function in MATLAB so for analysis of BER in WG fading channel, MATLAB code has been written for bivariate Meijer-G function in this thesis work.

4.2.2.2 Closed form expressions of BER for M-PAM modulation technique under dual SC diversity scheme over GGD noise

ABER for multi-level PAM in WG distribution has been derived. CEP for M-PAM signaling over AWGGN (GGD noise) is defined as [30]

$$P_e(E/\gamma)=Q_\alpha\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)=2\cdot\left(1-\frac{1}{M}\right)\cdot\frac{1}{2\Gamma(1/p)}G^{2,0}_{1,2}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)\right|^p\middle|\begin{matrix}1\\(0,1/p)\end{matrix}\right) \tag{4.23}$$

Substituting Eqn. (4.6) and (4.23) in Eqn. (4.8)

$$P_e\left(E\right)_{M-PAM} = 2\cdot\left(1-\frac{1}{M}\right)\cdot\int_0^\infty \frac{1}{2\Gamma(1/p)} G\,{}^{2,0}_{1,2}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)\right|^p \middle| \begin{matrix} 1 \\ (0,1/p) \end{matrix}\right)\cdot f_\gamma\left(\gamma\right)_{SC(WG)}d\gamma \tag{4.24}$$

Above equation divided into two parts

$$P_e(E)_{M-PAM} = P_{e11}(E)+P_{e22}\left(E\right) \tag{4.25}$$

$$\begin{aligned} P_{e11}(E) = 2\cdot\left(1-\frac{1}{M}\right)\cdot\int_0^\infty \Xi_1\gamma^{(3\beta/2+\lambda-2)}\cdot\frac{1}{2\Gamma(1/p)}\cdot G\,{}^{2,0}_{1,2}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)\right|^p \middle| \begin{matrix} 1 \\ (0,1/p) \end{matrix}\right) \\ G^{k+\lambda,1}_{1,k+\lambda+1}\left(\left[\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k}\right]\middle| \begin{matrix} 1-1/k \\ b_{k+\lambda},-1/k \end{matrix}\right)\cdot \\ G^{k+\lambda,2}_{2,k+\lambda+2}\left(\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k}\middle| \begin{matrix} (0),(1-1/k) \\ (b)_{k+\lambda},(-1/k),(1) \end{matrix}\right)d\gamma \end{aligned} \tag{4.26}$$

$$\begin{aligned} P_{e22}(E) = 2\cdot\left(1-\frac{1}{M}\right)\cdot\int_0^\infty \Xi_2\left(\gamma^{(3\beta/2-1)}\right)\cdot\frac{1}{2\Gamma(1/p)}\cdot G\,{}^{2,0}_{1,2}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)\right|^p \middle| \begin{matrix} 1 \\ (0,1/p) \end{matrix}\right)\cdot \\ G^{k+\lambda,1}_{1,k+\lambda+1}\left(\left[\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k}\right]\middle| \begin{matrix} 1-1/k \\ b_{k+\lambda},-1/k \end{matrix}\right) \\ G^{k+\lambda,1}_{1,k+\lambda+1}\left(\frac{\left[\alpha\Gamma(1+2/\beta)\gamma\right]^\lambda}{(\bar{\gamma}\lambda)^\lambda k^k}\middle| \begin{matrix} 1-1/k \\ b_{k+\lambda},-1/k \end{matrix}\right)d\gamma \end{aligned} \tag{4.27}$$

Solution for the Eqn. (4.26) and (4.27) which is also given in bivariate Meijer-G function can be used from Eqn. (4.22) and put it into Eqn. (4.25) for evaluating ABER for M-PAM under dual SC for WG , MATLAB code has been written.

4.3 SIMULATED RESULTS AND DISCUSSION:

In this section, system performance has been evaluated in term of ABER for two modulation techniques (BPSK, M-PAM) under dual SC with composite WG distribution over GGD noise. β is the distribution shaping parameter, α is shadowing parameter and ‘ p ’ is noise shaping parameter are the parameters used for the analysis. Therefore distinct values of ‘ p ’ and arbitrary value of ‘ α ’ and ‘

β ' are taken into consideration. MATLAB 15 software is used to simulate the results. All derived equations is represented in term of bivariate Meijer G function.

Figure 4.1 represent the PDF of WG shadowed fading channel under dual SC diversity scheme with distinct values of shadowing parameter α and fixed fading parameter β.

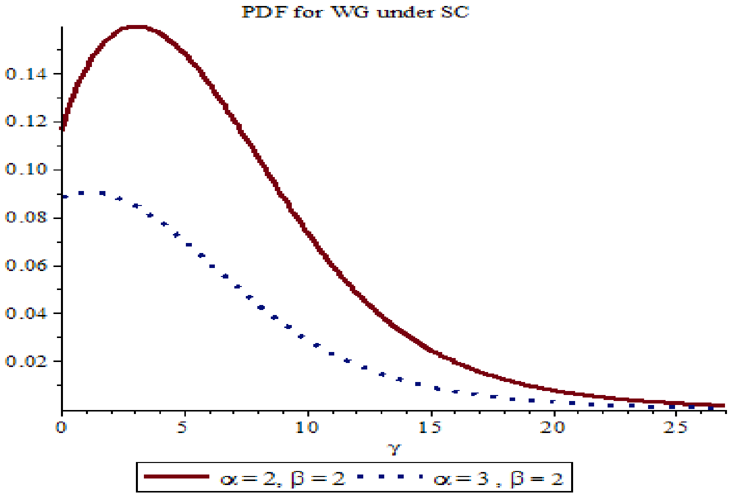

Figure 4.1 PDF of WG under SC scheme for different α keeping β fixed

At 0 dB SNR, PDF value is 0.12 for lower value of ' α ' and approximately 0.09 at higher value of ' α '. However, maximum amplitude for ' α ' = 3 has been achieved at less than 5 dB SNR whereas ' α '=2 pick up their maximum peak value at 5 dB SNR value. Further, as the value of SNR increases, the in both case, reduction in PDF values occur for both value of ' α '. But between 10 to 15 dB SNR, reduction for higher value of ' α ' is more as compared with lower value of ' α '. Therefore, conclusion with above graph is as the value of ' α ' increases, the amplitude value with respect to that value of ' α ' decreases which is expected.

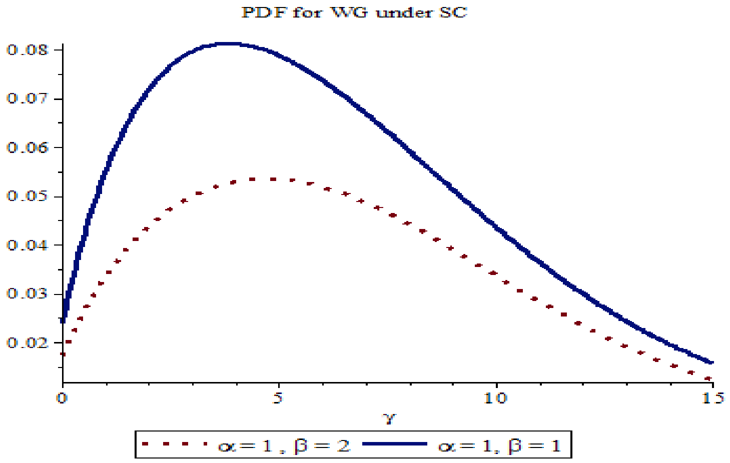

Figure 4.2 PDF of WG under SC scheme for different β keeping α fixed.

Figure 4.2 shows comparison between distinct values of fading parameter ‘β’ with fixed ‘α’ of shadowing parameter. This figure shows the same concept means as the value of ‘β’ increases, reduction in PDF value occur. Hence, for higher values of ‘β’ more reduction in PDF presents less severity for fading and system performance is expected to improve.

Figure 4.3 illustrates the performance of system in term of ABER which is derived in equation 4.11. ABER versus SNR curves between dual SC scheme and no SC scheme with fixed values of ‘α’=1 and ‘β’ =2 has been presented.

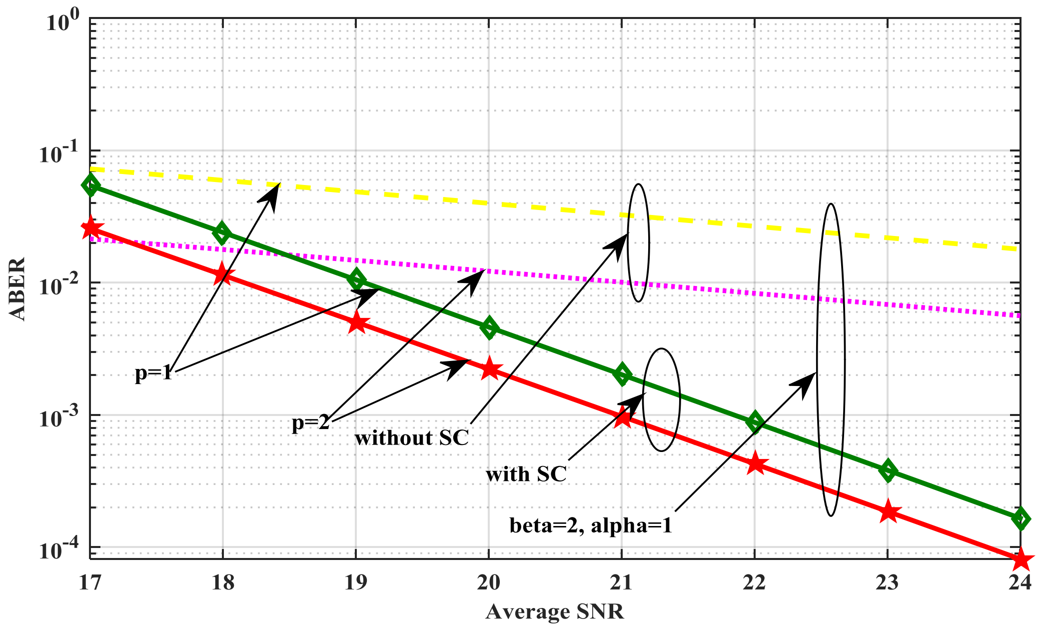

Figure 4.3 ABER v/s ASNR plot for dual SC and no diversity under WG fading channel subject to GGD noise for BPSK

According to the graph at 18 dB SNR, ABER for dual SC is 10^{-2} over Gaussian noise for low SNR region. However, for the same scenario ABER value with no SC result is more than 10^{-2}. Further, for high SNR region proposed result ABER value is 10^{-3} under Laplacian noise and for existing result its value is lying between 10^{-1} and 10^{-2} at 22 dB SNR. It is to be noted that with these results ABER value is less for SC diversity scheme for same fading and shadowing value with identical SNR over GGD noise. This extent of reduction in ABER value for dual SC case indicates the reduction in fading severity is more for proposed result. The analysis of ABER in NC is desirable. Thus, less ABER for proposed result compare with literature ABER over WG shadowed fading channel shows improvement in system performance for the proposed model. Hence, demand for improving communication process in the presence of noise and fading for NC has been fulfilled with the validation of comparison results.

In NC, analysis of BER is essential. Thus, ABER in figure 4.4 has been analyzed under dual SC with proposed WG fading channel over Gaussian noise. In this graph, numerical result has been presented for arbitrary values of shadowing parameter 'α' while keeping noise shaping and fading parameter fixed.

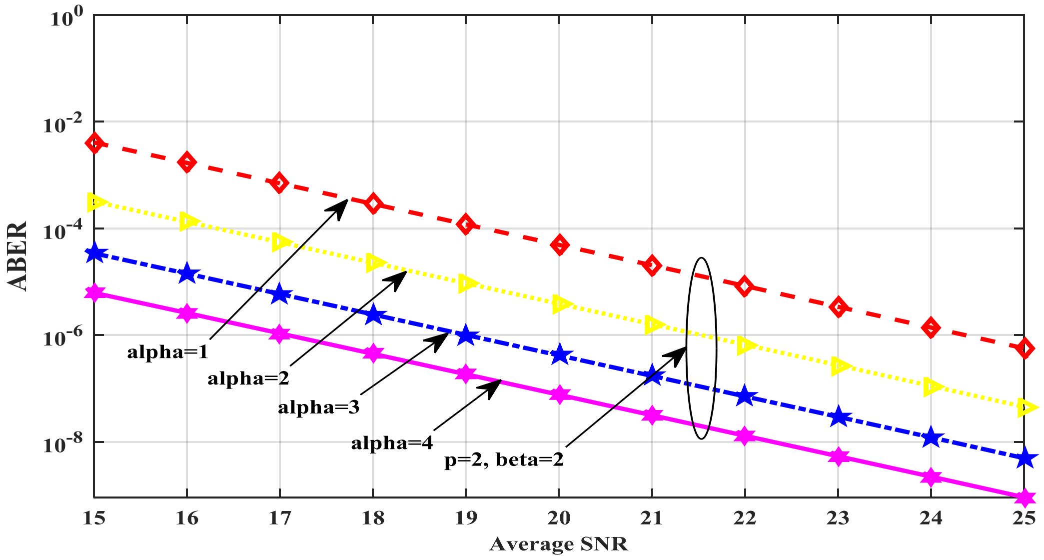

Figure 4.4 ABER v/s ASNR plot under shadowing parameter of WG fading at BPSK over Gaussian noise for dual SC

At 19 dB SNR, ABER is 10^{-4} for 'α'= 1. However, as 'α' varies from 1 to 2 ABER value is lying between 10^{-4} to 10^{-6}. Similarly, variation in 'α' from 2 to 3 shows ABER at 10^{-6} for same SNR. But as 'α' changing from 3 to 4, Reduction in ABER is less than the reduction in all the above ABER values. With this observation we can conclude that amount of fading severity in 'α'= 1, 2 and 3 for fixed 'β' = 2 at constant SNR is same. This similar type of reduction in fading severity is due to reduction in ABER is 10^{-1}. Although reduction in ABER for 'α'= 4 is less than 10^{-1} shows fading severity is more.

Impact of fading parameter ‘ β ’ on the performance of ABER with constant values of noise shaping parameter ‘ p ’ and shadowing parameter ‘ α ’ has been illustrated in figure 4.5.

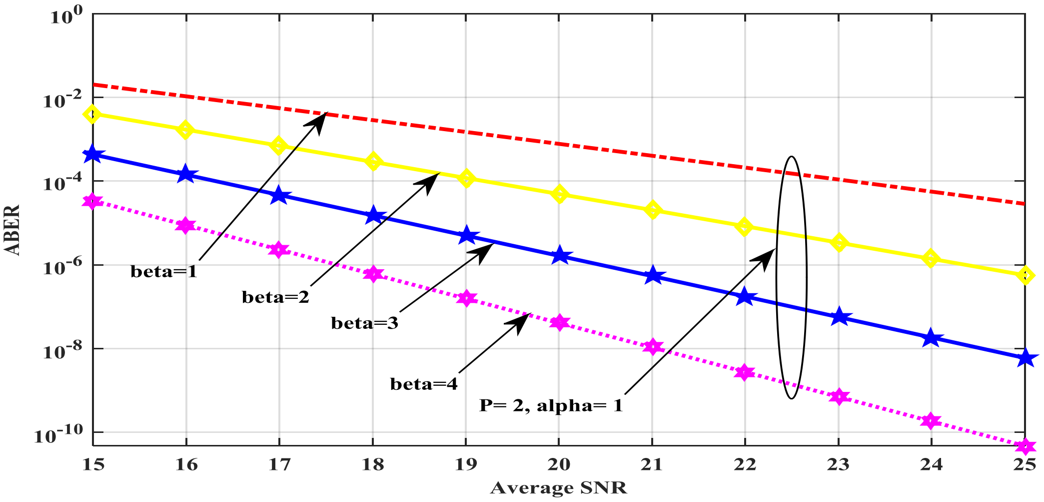

Figure 4.5 ABER v/s ASNR plot with dual SC under WG fading channel for BPSK over Gaussian noise

Condition for improvement in system performance in wireless communication is less value of ABER is required. This condition is valid for NC also. Through figure 4.5, we observed that the effect of fading parameter on ABER at low SNR region is more. But as the SNR value is increased and tends towards high SNR region the effect of fading and noise is getting reduced with more reduction in ABER value compare with low SNR region. However, effect of shadowing in figure 4.4 is almost uniform for both the high and low SNR region. Similar type of noise that is Gaussian has been considered for both the figures. Thus, by seeing in the both the figures this observation is validating clearly.

ABER performance of WG shadowed fading channel under dual SC when BPSK is employed over GGD noise has been discussed in figure 4.6. Numerical result is obtained by using 4.11 equation for two values of noise shaping parameter p and two values of shadowing parameter ‘ α ’.

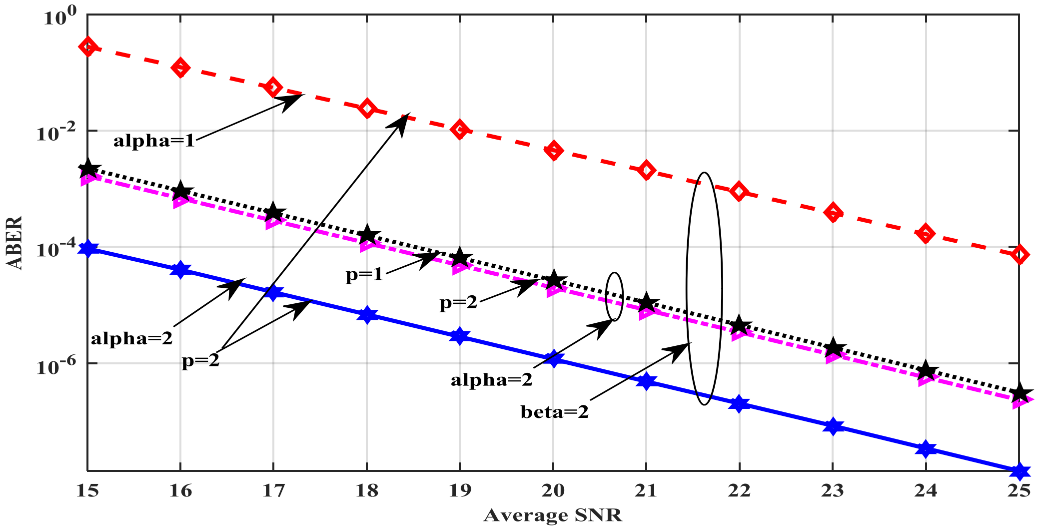

Figure 4.6 ABER v/s ASNR plot for dual SC under WG fading channel subject to GGD noise for BPSK

The system performance in term of ABER is improved at higher value of GGD noise parameter ‘ p ’ and higher value of fading and shadowing parameter. According to graph, the variation in the value of ABER is very less for complete SNR region at Laplacian noise and Gaussian noise for both ‘ α ’ and ‘ β ’=2. Whereas, when graph is plot for shadowing parameter ‘ α ’= 1 and 2 then variation in the value of ABER is large for Gaussian noise. Also reduction in ABER is more at higher value of ‘ α ’. It concludes that for less value of ‘ α ’ error dominates by fading but as the value of ‘ α ’ is increases then due to presence of additive noise, error tends to be more. Observation for figure 4.6 is fading severity in case of shadowing parameter with Gaussian noise is less with less ABER value. Moreover, the same trend here is also followed by shadowing parameter which shows the effect of fading and noise on the performance of system. Variation in the value of ABER is almost uniform for the entire range of SNR.

Aforementioned closed form expression proposed in 4.25 for M-PAM has been considered in figure 4.7 for the analysis of ABER. This analysis has been performed under the effect of AWGGN (GGD) channel with the fixed value of 'α', 'β' and 'M'.

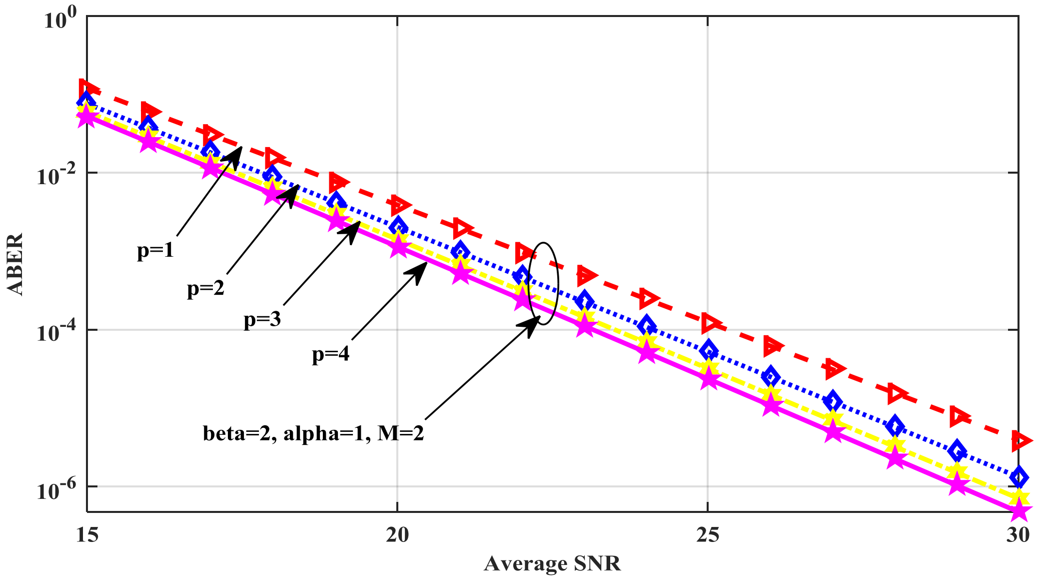

Figure 4.7 ABER for 2-PAM over GGD noise under dual SC for WG fading channel

Graph presents reduction in ABER for distinct values of 'p' at 'β' = 2, 'α'=1 and M=2. As 'p' changes from 1 to 2 for low SNR region (15-20 dB) then reduction in ABER is very less as noise varies from Laplacian to Gaussian. Further, when 'p' varies from 2 to 3 reduction in ABER is less than the above reduction and when 'p' changes from 3 to 4, ABER reduction is almost negligible. In this condition the effect of noise and fading is more on error. Whereas, variation in 'p' from 1 to 2 to 3 to 4 show reduction in ABER value is more for high SNR region (25-30 dB) than low SNR region. This observation concise that error has been influenced by noise at low SNR case but at high SNR, error value is increased means fading and noise severity is getting reduced.

Performance analysis of the system has been discussed in figure.4.8 through comparison between BPSK and 2-PAM modulation technique. ABER v/s ASNR curves has been plotted for shadowing parameter of WG fading channel 'α' with fading parameter 'β' under Gaussian noise. Graph in figure 4.8 represents the ABER value at 19 dB SNR for BPSK is 10^{-2} and for 2-PAM is 10^{-1} whereas, at 20 dB SNR, The ABER value for BPSK is 10^{-6} and for 2-PAM is 10^{-5}. This large amount of reduction in ABER with only one dB increment in SNR presents the advantage of using new modulation technique in this thesis.

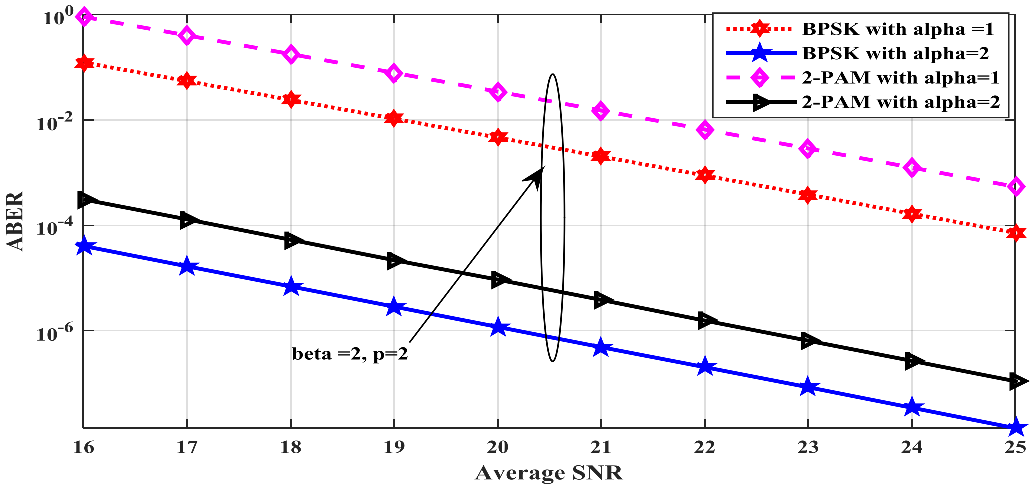

Figure 4.8 ABER v/s ASNR plot of dual SC for BPSK and 2-PAM over Gaussian noise under shadowed WG fading parameter.

Another observation has been indicated through this plot is ABER value is less in BPSK and more in 2-PAM with same no. of bits as expected. Hence improvement in system performance is more in BPSK case with less fading severity.

Figure 4.9 illustrates the evaluation of ABER v/s Average SNR for 8-PAM under dual SC scheme.

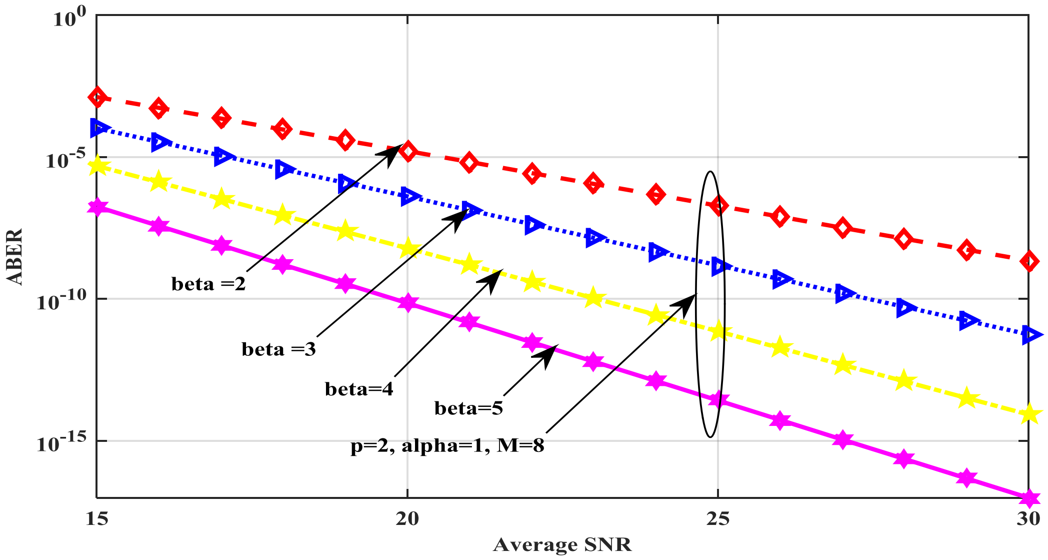

Figure 4.9 ABER v/s ASNR plot of dual SC under fading parameter for 8-PAM Gaussian noise.

In this plot reduction in the ABER value is lying between 10^{-5} to10^{-10} for low SNR region at 20 dB SNR. As the range of SNR value increases, reduction in ABER is also increases. Further reduction is shown for high SNR region (25-30 dB) in ABER. This trend has been followed by fading parameter of WG shadowed fading channel which implies impact of fading is getting reduced as the value of ABER is reduced. In other words, fading severity has been reduced as the value of fading parameter 'β' has been increased.

4.4 PERFORMANCE IMPROVEMENT TABLE FOR WG

Table 4.1 Comparison between dual SC diversity and no diversity for BPSK

Parameters	values	ASNR	Existing ABER	Proposed ABER
' p ' is noise shaping parameter	p =1represent Laplacian noise	19 dB	Less that 10^{-1} but More than 10^{-2}	10^{-2}
	p = 2 is Gaussian noise	21 dB	10^{-2}	10^{-3}

Table in 4.1 represents the comparison between the existing ABER and the Proposed ABER. This table clearly shows that the ABER value in proposed result is less in comparison with existing ABER at same SNR value. Hence, use of dual SC diversity scheme makes system performance better in the presence of both noise and fading.

Table 4.2 Comparison between BPSK and 2-PAM over Gaussian noise

Parameters	values	ASNR	BPSK ABER	M-PAM ABER
' α ' is shadowed parameter	α =1	19 dB	10^{-2}	10^{-1}
	α = 2	20 dB	10^{-6}	10^{-5}

Comparison between BPSK and M-PAM for analysis of the system performance in term of ABER has been discussed. According to table, when M-PAM with M=2 is plotted with BPSK then ABER in BPSK case is less than M-PAM

4.5 SUMMARY

The main focus of thesis work is to reduce the amount of impairments (fading and noise) from the system for making reliable transmission in EMNC-based BAN under CM1 scenario of NC. However, this mitigation has been accomplished through modeling of fading and shadowing by using a proposed composite fading distribution. Diversity scheme is best match for enhancing the possibility of receiving correct information. So, for this purpose a closed-form expression of ABER for the proposed PDF of WG under dual SC scheme over GGD noise has been proposed at different modulation techniques. A performance improvement table between proposed result and existing result at BPSK over Laplacian and Gaussian noise has been presented in section 4.4.1. This table represent if the value of noise shaping parameter is increased then reduction in ABER is achieved definitely. Thus, reduced amount of fading severity is received. Also comparison between BPSK and 2-PAM implies the ABER is less for BPSK compare with 2-PAM.

CHAPTER 5

CLOSED FORM EXPRESSIONS OF BER FOR MIXTURE-GAMMA

5.1 INTRODUCTION

Different types of distribution functions have been used for modeling the multipath fading and shadowing. Fading can be classified as large scale called macroscopic and as small scale called microscopic. Macroscopic is due to shadowing and microscopic is due to fading are modeled by fading/shadowing composite distribution. These distributions have some analytical difficulties at the time of modeling. To get rid of the analytical difficulties, a new composite shadowed fading channel with accurate approximation for lognormal shadowing has been proposed as MG distribution [10]. This distribution shows more accuracy for composite fading channels and is most generic form of fading channel till date. In this chapter proposed distribution is Mixture-gamma.

CEP for BPSK over GGD noise distribution has been used for evaluating ABER in [28]. GGD is a most generic noise distribution which contains different types of noise. In nano communication, AIGN and AWGN can be considered as noise model. AIGN is a special case of GGD, so GGD is best fitted to use as noise model. Diversity technique used in this work is SC which is optimum scheme than MRC and EGC [48]. In literature and also today’s modern communication, the tremendous condition which is still the same is its impairments. Due to presence of various impairments such as fading, noise, interference etc. performance analysis of the system is difficult to observe in NC. So Analysis of BER, channel capacity, outage probability using EMNC under CM1 scenario is a very difficult task in NC.

5.1.1 Statistical parameters for Mixture-Gamma fading channel

The statistical parameters for Mixture-Gamma distribution is its Probability Density Function (PDF), Cumulative Distribution Function(CDF), Moment Generating Function(MGF), Mean, Variance and Amount of Fading.

5.1.1.1 Cumulative Distribution Function (CDF)

CDF or distribution function X is a probability for X which takes value equal to or less than x (on which X evaluated). The use of CDF functions is to specify the distribution for multivariate random variables.

5.1.1.2 Moment Generating Function (MGF)

MGF can be considered as an alternative specification for probability distribution of real-valued random variable. It worked as an alternative route for analytical results.

MGF for MG can be defined as [11]:

$$\mathrm{M}_{\gamma}(x)=\sum_{j=1}^{N}\frac{\alpha_j\cdot\Gamma(\beta_j)}{(x+\xi_j)^{\beta_j}} \tag{5.1}$$

Where, $\mathrm{M}_{\gamma}(x)=E(e^{-xy})$ with $E(.)$which denotes expectation operator.

PDF and CDF of MG have been considered in deriving the PDF under dual SC for analyzing the BER.

However, in this chapter PDF under dual SC with proposed MG has been derived in 5.2.1 section. Moreover, in section 5.2.1 ABER under dual SC with MG at different modulation techniques over GGD noise has been analyzed. In section 5.3, numerical analysis has been performed. Further, performance improvement table between literature result and the proposed result has been presented in 5.4 section. Lastly summary has been discussed of the whole chapter in 5.5 section.

5.2 MATHEMATICAL CHANNEL MODEL FOR MIXTURE-GAMMA FADING CHANNEL DISTRIBUTION

In this section, composite fading channel MG has been considered for modeling fading and shadowing in EMNC based BAN under CM1 SC1 in nano communication. Also to model noise in EMNC, GGD a generalized noise model has been used. PDF under dual SC has been derived and closed form expression with proposed PDF for calculating ABER using CEP of different modulation techniques over GGD noise distribution has also been derived.

5.2.1 Proposed PDF of Mixture-Gamma under dual SC diversity scheme

When the received envelope of slowly varying fading channel is γ having received energy as E_s with single sided PSD of GGD noise is N_0. SNR is calculated using E_s and N_0 So, The SNR PDF for Mixture Distribution can be defined as [11]

$$f_{\gamma}(\gamma)=\sum_{i=0}^{N}w_i\cdot f_i(\gamma)=\sum_{i=0}^{N}\alpha_i\cdot\frac{\gamma^{\beta_i-1}}{\bar{\gamma}}\cdot e^{\frac{-\xi_i\gamma}{\bar{\gamma}}} \quad , \quad \gamma=>0 \tag{5.2}$$

Where α_i , β_i and ξ_i are the parameters of Gamma component with ith order and $\bar{\gamma}$ is average SNR defined as, $\bar{\gamma}=\Gamma\left(1+\frac{2}{\beta}\right)\cdot\Omega^{\frac{2}{\beta}}\cdot\frac{E_s}{N_O}$

The CDF of SNR for MG can be evaluated as [11]

$$F_\gamma(\gamma)=\sum_{i=1}^{N}\alpha_i\cdot\xi_i^{-\beta_i}\cdot\gamma\left(\beta_i,\frac{\xi_i\gamma}{\bar{\gamma}}\right) \tag{5.3}$$

Where, $\gamma\left(\beta_i,\frac{\xi_i\gamma}{\bar{\gamma}}\right)=\left(\frac{\xi_i}{\bar{\gamma}}\right)^{\beta_i}\cdot\gamma^{\beta_i}\cdot\Gamma(\beta_i)\cdot e^{\frac{-\xi_i\gamma}{\bar{\gamma}}}\cdot\sum_{k=0}^{\infty}\frac{\left(\frac{\xi_i\gamma}{\bar{\gamma}}\right)^k}{\Gamma(\beta_i+k+1)}$ represent the lower incomplete Gamma function [68]. Here, N denotes the no. of terms which is different for various fading model.

5.2.1.1 Diversity Technique

This is a most effective technique when multipath fading occurs. It helps for choosing a signal with less amount of error. Sometime diversity needs to be applied with a fading channel for alleviate the effect of fading. So, In this thesis, fading distribution MG is considered with SC diversity scheme. Formula used for evaluating the PDF under SC can be written as [57]

$$f_\gamma(\gamma)\big|_{SC(MG)}=M\left[F_\gamma(\gamma)\right]^{M-1}f_\gamma(\gamma) \tag{5.4}$$

M is a no. of branches needs in diversity, $f_\gamma(\gamma)$ and $F_\gamma(\gamma)$ is the PDF and CDF of fading channel for which PDF is evaluated.

Plugging Eqn. (5.2) and (5.3) in Eqn. (5.4), we get with M =2 denotes dual SC

$$f_\gamma(\gamma)_{SC(MG)}=2\left(\sum_{i=1}^{N}\alpha_i\cdot\xi_i^{-\beta_i}\cdot\gamma\left(\beta_i,\frac{\xi_i\gamma}{\bar{\gamma}}\right)\right)^{2-1}\cdot\sum_{i=0}^{N}\alpha_i\cdot\frac{\gamma^{\beta_i-1}}{\bar{\gamma}}\cdot e^{\frac{-\xi_i\gamma}{\bar{\gamma}}} \tag{5.5}$$

After substituting the value of lower incomplete gamma function in Eqn. (5.5) then Eqn. (5.5) gives the PDF under Dual SC

$$f_\gamma(\gamma)_{SC(MG)}=\sum_{i=0}^{N}\sum_{k=0}^{\infty}2\cdot(\alpha_i)^2\cdot\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_i}\cdot\frac{\Gamma(\beta_i)}{\Gamma(\beta_i+k+1)}\cdot\left(\frac{\xi_i}{\bar{\gamma}}\right)^k\cdot e^{\frac{-2\cdot\xi_i\gamma}{\bar{\gamma}}}\cdot\gamma^{2\cdot\beta_i-1+k} \tag{5.6}$$

Mixture Gamma distribution which is used as a fading channel is most Generic form till date ,due to this we can easily convert it into another fading channel by choosing N, So N=1 reverts to Nakagami-m fading channel and Rayleigh fading channel but we considered Nakagami-m fading

Eqn. (5.6) reduced by applying M=2

$$f_\gamma(\gamma)_{SC(MG)}=\sum_{k=0}^{\infty}2\cdot(\alpha_1)^2\cdot\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_1}\times\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\cdot\left(\frac{\xi_1}{\bar{\gamma}}\right)^k\cdot e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}}\cdot\gamma^{2\cdot\beta_1-1+k} \tag{5.7}$$

At N=1, Nakagami-m fading channel is considered and parameter values is given as [11]

$$\alpha_1 = \frac{m^m}{\Gamma(m)\cdot\left(\bar{\gamma}\right)^m} \quad , \quad \beta_1 = m \text{ and } \xi_1 = \frac{m}{\bar{\gamma}} \tag{5.8}$$

Here, In Nakagami-m fading 'm' denotes its fading parameter

5.2.2 Closed form expressions of BER at different modulation techniques over GGD noise under dual SC diversity scheme

In this section, expression for analyzing the ABER using MG distribution has been proposed under Dual SC diversity scheme with Generalized Gaussian Distribution as a noise. Various types of modulation schemes like BPSK, M-PAM, M-QAM are considered for calculating ABER.

General definition for evaluating BER is defined as [28]

$$P_e(E) = \int_0^\infty P_e(E/\gamma)\cdot f_\gamma(\gamma)d\gamma \tag{5.9}$$

Here, $P_e(E)$ calculate the BER and observed how many bits received as a error dividing by total no. of bits. BER shows either improvement or degradation in the performance of system.

5.2.2.1 Closed form expression of BER for BPSK modulation technique under dual SC diversity scheme over GGD noise

Proposed Conditional Error probability (CEP) for BPSK over GGD noise has been used for deriving the closed form expression of ABER. CEP can be written as [29].

$$P_e(E/\gamma) = Q_\alpha\left(\sqrt{2\gamma}\right) = \frac{1}{2\Gamma(1/p)} G_{1,2}^{2,0}\left(\Lambda_0^p\left|\left(\sqrt{2\gamma}\right)^p\right| \begin{matrix} 1 \\ (0,1/p) \end{matrix}\right) \tag{5.10}$$

Where $\Gamma(.)$ is a Gamma function, $\wedge_0 = \sqrt{\frac{\Gamma\left(\frac{3}{p}\right)}{\Gamma\left(\frac{1}{p}\right)}}$ is a normalized noise power.

Substituting Eqn. (5.7) and (5.10) in Eqn. (5.9)

$$P_e(E)_{BPSK} = \int_0^\infty Q_\alpha\left(\sqrt{2\cdot\gamma}\right)\cdot f_\gamma(\gamma)_{SC(MG)}d\gamma \tag{5.11}$$

$$P_e(E)_{BPSK} = \int_0^\infty \frac{1}{2\Gamma(1/p)} G_{1,2}^{2,0}\left(\Lambda_0^p\left|\left(\sqrt{2\gamma}\right)^p\right| \begin{matrix} 1 \\ (0,1/p) \end{matrix}\right) \sum_{k=0}^\infty 2\cdot(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_1} \times \frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\left(\frac{\xi_1}{\bar{\gamma}}\right)^k e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}} \gamma^{2\cdot\beta_1-1+k}d\gamma \tag{5.12}$$

After some mathematical arrangement

$$P_e(E)_{BPSK}=\sum_{k=0}^{\infty}2\cdot(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_1}\times\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\cdot\left(\frac{\xi_1}{\bar{\gamma}}\right)^{k}\cdot$$
$$\int_0^{\infty}\frac{1}{2\Gamma(1/p)}G_{1,2}^{2,0}\left(\Lambda_0^p\left|\left(\sqrt{2\gamma}\right)\right|^p\middle|\begin{matrix}1\\(0,1/p)\end{matrix}\right)\cdot e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}}\gamma^{2\cdot\beta_1-1+k}d\gamma \tag{5.13}$$

Solution for Eqn. (5.11) equation is taken from [70]

$$\int_0^{\infty}x^{\alpha-1}e^{-\sigma x}H_{p,q}^{m,n}\left[\omega x^r\middle|\begin{matrix}[a_p,A_p]\\[b_q,B_q]\end{matrix}\right]dx=\sigma^{-\alpha}H_{p+1,q}^{m,n+1}\left[\frac{\omega}{\sigma^r}\middle|\begin{matrix}(1-\alpha,r)[a_p,A_p]\\[b_q,B_q]\end{matrix}\right] \tag{5.14}$$

On comparison Eqn. (5.14) with Eqn. (5.13)

$\alpha=2\cdot\beta_1+k,\ \sigma=\frac{2\cdot\xi_1}{\bar{\gamma}},\ \omega=\left(\wedge_0\cdot\sqrt{2}\right)^p,\ r=\frac{p}{2}$ and $m=2,\ n=0,\ p=1,\ q=2$

After putting all values in Eqn. (5.13), we get

$$P_e(E)_{BPSK}=\sum_{k=0}^{\infty}2(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\beta_1}\frac{1}{2\Gamma(1/p)}\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\left(\frac{\xi_1}{\bar{\gamma}}\right)^{k}$$
$$\left(\frac{2\xi_1}{\bar{\gamma}}\right)^{-(2\beta+k)}G_{2,2}^{2,1}\left(\frac{\left(\sqrt{2}\cdot\wedge_0\right)^P}{\left(\frac{2\cdot\xi}{\bar{\gamma}}\right)^{\frac{P}{2}}}\middle|\begin{matrix}(1-2\cdot\beta_1-k,1)\\(\frac{1}{p},0)\end{matrix}\right) \tag{5.15}$$

The above mentioned Eqn. (5.15) represents ABER for BPSK in the form of sum series with Meijer G function.

5.2.2.2 Closed form expression of BER for M-PAM modulation technique under dual SC diversity scheme over GGD noise

Pulse Amplitude Modulation is a type of analog modulation technique where encoding in modulating signal occur according to the variation in the amplitude of the carrier pulse train. Multi level PAM means providing a way to reduce the pulse amplitude numbers at some power of 2.

Example: 4-level PAM means 2^2 pulse amplitude is possible with 2 bits.

For deriving the ABER using M-PAM, CEP of M-PAM is defined as [30]:

$$P_e(E/\gamma)=Q_\alpha\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)=2\cdot\left(1-\frac{1}{M}\right)\frac{1}{2\Gamma(1/p)}G_{1,2}^{2,0}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)\right|^p\middle|\begin{matrix}1\\(0,1/p)\end{matrix}\right) \tag{5.16}$$

Here, d is a minimum distance b/w symbols and M = 2^k or k= $\log_2(M)$ where k represents the no. of bits per symbol.

Putting Eqn.(5.16) and (5.7) in Eqn. (5.9)

$$P_e(E)_{M-PAM} = 2\cdot\left(1-\frac{1}{M}\right)\cdot\int_0^\infty \frac{1}{2\Gamma(1/p)} G_{1,2}^{2,0}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)\right|^p \middle| \begin{matrix} 1 \\ (0,1/p) \end{matrix}\right)\cdot f_\gamma(\gamma)_{SC(MG)}\,d\gamma \quad (5.17)$$

$$P_e(E)_{M-PAM} = 2\cdot\left(1-\frac{1}{M}\right)\cdot\int_0^\infty \frac{1}{2\Gamma(1/p)} G_{1,2}^{2,0}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)\right|^p \middle| \begin{matrix} 1 \\ (0,1/p) \end{matrix}\right)\cdot$$

$$\sum_{k=0}^{\infty} 2\cdot(\alpha_1)^2\cdot\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_1}\times\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\cdot\left(\frac{\xi_1}{\bar{\gamma}}\right)^k\cdot e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}}\cdot\gamma^{2\cdot\beta_1-1+k}\,d\gamma \quad (5.18)$$

$$P_e(E)_{M-PAM} = 2\cdot\left(1-\frac{1}{M}\right)\cdot\sum_{K=0}^{\infty} 2\cdot(\alpha_1)^2\cdot\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_1}\times\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\cdot\left(\frac{\xi_1}{\bar{\gamma}}\right)^k\cdot\frac{1}{2\Gamma(1/p)}\cdot$$

$$\int_0^\infty G_{1,2}^{2,0}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\frac{d}{\sigma}\right)\right)\right|^p \middle| \begin{matrix} 1 \\ (0,1/p) \end{matrix}\right) e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}}\cdot\gamma^{2\cdot\beta_1-1+k}\,d\gamma \quad (5.19)$$

Solution for the Eqn. (5.19) equation can be written as [70]:

$$\int_0^\infty x^{\alpha-1}e^{-\sigma x}H_{p,q}^{m,n}\left[\omega x^r\left|\begin{matrix}[a_p,A_p]\\ [b_q,B_q]\end{matrix}\right.\right]dx=\sigma^{-\alpha}H_{p+1,q}^{m,n+1}\left[\frac{\omega}{\sigma^r}\left|\begin{matrix}(1-\alpha,r)[a_p,A_p]\\ [b_q,B_q]\end{matrix}\right.\right] \quad (5.20)$$

On comparing Eqn. (5.20) with Eqn. (5.19)

$\alpha = 2\cdot\beta_1 + k$, $\sigma = \frac{2\cdot\xi_1}{\bar{\gamma}}$, $\omega = \left(\wedge_0\cdot\frac{d}{\sigma}\right)^p$, $r = \frac{p}{2}$ and m =2, n =0, p =1, q =2

After all mathematical calculation, the equation for evaluating the ABER has been proposed.

$$P_e(E)_{M-PAM} = \sum_{k=0}^{\infty}\left(\frac{2\xi_1}{\bar{\gamma}}\right)^{-(2\beta+k)} G_{2,2}^{2,1}\left(\frac{\left(\sqrt{2}\cdot\wedge_0\right)^P}{\left(\frac{2\cdot\xi}{\bar{\gamma}}\right)^{\frac{P}{2}}}\middle|\begin{matrix}(1-2\cdot\beta_1-k,1)\\ (\frac{1}{p},0)\end{matrix}\right) 2(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\beta_1}\frac{1}{2\Gamma(1/p)}$$

$$\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\left(\frac{\xi_1}{\bar{\gamma}}\right) \tag{5.21}$$

5.2.2.3 *Closed form expression of BER for M-QAM modulation technique under dual SC diversity scheme over GGD noise*

QAM means quadrature amplitude modulation in which two carrier signals with 90 degree phase difference are transmitted and added at the receiver side. It is called quadrature because of the 90 degree phase shift b/w signals. By using PAM as in phase and quadrature, QAM signal is formed. It is due to the existence of quadrature and in-phase signal in QAM signal.

CEP of M-QAM over AWGGN channel (GGD noise) has been proposed in literature. It is used in this section for evaluating the ABER and defined as [30]

$$P_e(E/\gamma)=4\left(1-\frac{1}{\sqrt{M}}\right)\cdot Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)-4\left(1-\frac{1}{\sqrt{M}}\right)^2\cdot Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)^2 \tag{5.22}$$

Where,

$$Q_\alpha\left(\sqrt{\frac{3\cdot\gamma}{M-1}}\right)=\frac{1}{2\Gamma(1/p)}G_{1,2}^{2,0}\left(\Lambda_0^p\left|\left(\sqrt{\gamma}\left(\sqrt{\frac{3}{M-1}}\right)\right)\right|^p\left|\begin{matrix}1\\(0,1/p)\end{matrix}\right.\right)$$

Plugging Eqn. (5.7) and (5.22) in Eqn. (5.9)

$$P_e(E)_{M-QAM}=\int_0^\infty\left(4\left(1-\frac{1}{\sqrt{M}}\right)\cdot Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)-4\left(1-\frac{1}{\sqrt{M}}\right)^2\cdot Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)^2\right)\cdot f_\gamma(\gamma)_{SC(MG)}d\gamma \tag{5.23}$$

$$\begin{aligned}P_e(E)_{M-QAM}=&\int_0^\infty 4\left(1-\frac{1}{\sqrt{M}}\right)\cdot Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)\sum_{k=0}^\infty 2\cdot(\alpha_1)^2\cdot\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_1}\times\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\cdot\left(\frac{\xi_1}{\bar{\gamma}}\right)^k\cdot e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}}\cdot\gamma^{2\cdot\beta_1-1+k}d\gamma\\&-\int_0^\infty 4\left(1-\frac{1}{\sqrt{M}}\right)^2 Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)^2\sum_{k=0}^\infty 2\cdot(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_1}\\&\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\cdot\left(\frac{\xi_1}{\bar{\gamma}}\right)^k\cdot e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}}\cdot\gamma^{2\cdot\beta_1-1+k}d\gamma\end{aligned} \tag{5.24}$$

Eqn. (5.24) can be written as

$$P_e(E)_{M-QAM} = P_e(E)_{M-QAM1} + P_e(E)_{M-QAM2} \tag{5.25}$$

$$P_e(E)_{M-QAM1} = \int_0^\infty 4\left(1-\frac{1}{\sqrt{M}}\right)\cdot Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)\sum_{k=0}^{\infty}2\cdot(\alpha_1)^2\cdot\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_1}\times\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\cdot\left(\frac{\xi_1}{\bar{\gamma}}\right)^k\cdot e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}}\cdot\gamma^{2\cdot\beta_1-1+k}d\gamma \tag{5.26}$$

$$P_e(E)_{M-QAM2} = \int_0^\infty 4\left(1-\frac{1}{\sqrt{M}}\right)^2 Q_\alpha\left(\sqrt{\frac{3\gamma}{M-1}}\right)^2\sum_{k=0}^{\infty}2\cdot(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\cdot\beta_1}\times\frac{\Gamma(\beta_1)}{\Gamma(\beta_1+k+1)}\cdot\left(\frac{\xi_1}{\bar{\gamma}}\right)^k e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}}\gamma^{2\cdot\beta_1-1+k}d\gamma \tag{5.27}$$

Series expansion of exponential function [69]

$$e^{\frac{-2\cdot\xi_1\cdot\gamma}{\bar{\gamma}}} = \sum_{i=0}^{\infty}\frac{\left(\frac{-2\xi_1}{\bar{\gamma}}\right)^i\cdot(\gamma)^i}{(i)!} \tag{5.28}$$

After series expansion above equation can be re-written as:

$$P_e(E)_{M-PAM2} = -\left(\frac{2}{\Gamma\left(\frac{1}{p}\right)^2}\right)\left(1-\frac{1}{\sqrt{M}}\right)^2\sum_{i=0}^{\infty}\sum_{K=0}^{\infty}\frac{\left(\frac{2\xi_1}{\bar{\gamma}}\right)^i}{(i)!}2(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\beta_1}\frac{\Gamma\beta_1}{\Gamma(\beta_1+k+1)}\left(\frac{\xi_1}{\bar{\gamma}}\right)^k\cdot$$

$$\int_0^\infty\gamma^{\left(\frac{4\beta_1}{p}-\frac{4}{p}+\frac{2k}{p}+\frac{2i}{p}+2\right)-1}H_{1,2}^{2,0}\left[\left(\frac{\wedge_0\sqrt{3}}{\sqrt{M-1}}\right)^p\gamma\left|\begin{matrix}(1,1)\\ \left(\frac{1}{p},1\right),(0,1)\end{matrix}\right.\right]H_{1,2}^{2,0}\left[\left(\frac{\wedge_0\sqrt{3}}{\sqrt{M-1}}\right)^p\gamma\left|\begin{matrix}(1,1)\\ \left(\frac{1}{p},1\right),(0,1)\end{matrix}\right.\right]d\gamma \tag{5.29}$$

$$P_e(E)_{M-QAM2} = -\left(\frac{2}{\Gamma\left(\frac{1}{p}\right)^2}\right)\left(1-\frac{1}{\sqrt{M}}\right)^2\sum_{i=0}^{\infty}\sum_{K=0}^{\infty}\frac{\left(\frac{2\xi_1}{\bar{\gamma}}\right)^i}{(i)!}2(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\beta_1}\frac{\Gamma\beta_1}{\Gamma(\beta_1+k+1)}\left(\frac{\xi_1}{\bar{\gamma}}\right)^k y \tag{5.30}$$

Where,

$$y = \int_0^\infty \gamma^{\left(\frac{4\beta_1}{p} - \frac{4}{p} + \frac{2k}{p} + \frac{2i}{p} + 2\right) - 1} H_{1,2}^{2,0}\left[\left(\frac{\wedge_0 \sqrt{3}}{\sqrt{M-1}}\right)^p \gamma \middle| \begin{matrix} (1,1) \\ \left(\frac{1}{p},1\right),(0,1) \end{matrix}\right] H_{1,2}^{2,0}\left[\left(\frac{\wedge_0 \sqrt{3}}{\sqrt{M-1}}\right)^p \gamma \middle| \begin{matrix} (1,1) \\ \left(\frac{1}{p},1\right),(0,1) \end{matrix}\right] d\gamma \tag{5.31}$$

Solution for Eqn. (5.26) is taken from [70]

$$P_e(E)_{M-QAM1} = \frac{4}{\Gamma\left(\frac{1}{p}\right)^2} \cdot \left(1 - \frac{1}{\sqrt{M}}\right) \cdot \sum_{k=0}^{\infty} 2(\alpha_1)^2 \left(\frac{1}{\bar{\gamma}}\right)^{2\beta_1} \frac{\Gamma(\beta_1)}{\Gamma(\beta_1 + k + 1)} \left(\frac{\xi_1}{\bar{\gamma}}\right)^k$$
$$\left(\frac{2 \cdot \xi_1}{\bar{\gamma}}\right)^{-(2\cdot\beta_1 + k)} G_{2,2}^{2,1}\left(\frac{\left(\sqrt{2}\cdot\wedge_0\right)^P}{\left(\frac{2\cdot\xi}{\bar{\gamma}}\right)^{\frac{P}{2}}} \middle| \begin{matrix} (1 - 2\cdot\beta_1 - k, 1) \\ (\frac{1}{p}, 0) \end{matrix}\right) \tag{5.32}$$

Solution for Eqn.(5.27) is from [69]:

$$\int_0^\infty \gamma^{\eta-1} H_{p,q}^{m,n}\left[\beta\gamma^\sigma \middle| \begin{matrix} a_p, A_P \\ b_q, B_q \end{matrix}\right] H_{P,Q}^{M,N}\left[w\gamma \middle| \begin{matrix} c_p, C_P \\ d_q, D_q \end{matrix}\right] d\gamma$$
$$= w^{-\eta} H_{p+Q,q+P}^{m+N,n+M}\left[\beta w^{-\sigma} \middle| \begin{matrix} (a_n, A_n), (1 - d_n - \eta D_q, \sigma D_q), (a_{n+1}, A_{n+1}) .... (a_p, A_p) \\ (b_m, B_m), (1 - c_p - \eta C_P, \sigma C_p), (b_{m+1}, B_{m+1}) .... (b_q, B_q) \end{matrix}\right] \tag{5.33}$$

To use given solution in Eqn. (5.33), we need to compare Eqn. (5.33) with Eqn. (5.21)

After comparison,

$$\eta = \frac{4\beta_1}{p} - \frac{4}{p} + \frac{2k}{p} + \frac{2i}{p} + 2,\ m = 2,\ n = 0,\ p = 1,\ q = 2,\ M = 2,\ N = 0,\ P = 1,\ Q = 2$$

$$\beta = w = \left(\frac{\wedge_0 \sqrt{3}}{\sqrt{M-1}}\right)^p,\ \sigma = 1,\ a_1 = 1,\ A_1 = 1,\ b_1 = \frac{1}{p},\ B_1 = 1,\ b_2 = 0,\ B_2 = 1,\ c_1 = 1,\ C_1 = 1,$$

$$d_1 = \frac{1}{p},\ D_1 = 1,\ d_2 = 0,\ D_2 = 1$$

Plugging all the values which we get after comparison in y with Meijer G conversion

$$y = \left(\frac{\wedge_0 \sqrt{3}}{\sqrt{M-1}}\right)^{-p(\eta)} G_{3,3}^{2,2}\left[1 \middle| \begin{matrix} (-\eta, 1-\eta), (1) \\ \left(\frac{1}{p}, 0\right), (-\eta) \end{matrix}\right] \tag{5.34}$$

After substituting Eqn. (5.34) in Eqn.(5.30), we get

$$P_e(E)_{M-QAM\,2} = -\left(\frac{2}{\Gamma\left(\frac{1}{p}\right)^2}\right)\left(1-\frac{1}{\sqrt{M}}\right)^2 \sum_{i=0}^{\infty}\sum_{K=0}^{\infty}\frac{\left(\frac{2\xi_1}{\bar{\gamma}}\right)^i}{(i)!}2(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\beta_1}\frac{\Gamma\beta_1}{\Gamma(\beta_1+k+1)}\left(\frac{\xi_1}{\bar{\gamma}}\right)^k$$

$$\left(\frac{\wedge_0\sqrt{3}}{\sqrt{M}-1}\right)^{-p(\eta)} G_{3,3}^{2,2}\left[1\left|\begin{matrix}(-\eta,1-\eta),(1)\\ \left(\frac{1}{p},0\right),(-\eta)\end{matrix}\right.\right] \qquad (5.35)$$

Inserting Eqn.(5.32) and (5.35) in Eqn. (5.25)

$$P_e(E)_{M-QAM} = \left(\frac{2}{\Gamma\left(\frac{1}{p}\right)^2}\right)\left(1-\frac{1}{\sqrt{M}}\right)\sum_{K=0}^{\infty}2(\alpha_1)^2\left(\frac{1}{\bar{\gamma}}\right)^{2\beta_1}\frac{\Gamma\beta_1}{\Gamma(\beta_1+k+1)}\left(\frac{\xi_1}{\bar{\gamma}}\right)^k \cdot$$

$$\left(\begin{matrix}\left(\frac{2\xi_1}{\bar{\gamma}}\right)^{-(2\beta_1+k)} G\,{}^{2,1}_{2,2}\left(\frac{\left(\frac{\sqrt{3}\cdot\wedge_0}{\sqrt{M-1}}\right)^P}{\left(\frac{2\cdot\xi}{\bar{\gamma}}\right)^{\frac{P}{2}}}\left|\begin{matrix}(1-2\cdot\beta_1-k,1)\\ (\frac{1}{p},0)\end{matrix}\right.\right)- \\ \left(1-\frac{1}{\sqrt{M}}\right)\sum_{i=0}^{\infty}\frac{\left(\frac{2\xi_1}{\bar{\gamma}}\right)^i}{(i)!}\left(\frac{\wedge_0\sqrt{3}}{\sqrt{M}-1}\right)^{-p(\eta)} G_{3,3}^{2,2}\left[1\left|\begin{matrix}(-\eta,1-\eta),(1)\\ \left(\frac{1}{p},0\right),(-\eta)\end{matrix}\right.\right]\end{matrix}\right) \qquad (5.36)$$

The aforementioned equation is used for analyzing the ABER under dual SC over GGD noise for M-QAM with proposed MG.

5.3. SIMULATED RESULTS AND DISCUSSION:

In this section, system evaluation has been performed in term of ABER for different modulation techniques (BPSK, M-PAM and M-QAM) under dual SC with composite MG distribution over GGD noise distribution. MG is a generalized composite fading channel means by changing the value of N it converted into another fading channel. Therefore, when N=1 MG reverts into Nakagami-m fading and Rayleigh fading channel and N is different for other fading channels. In this thesis work Nakagami-m fading channel has been considered which one of the cases of MG distribution. ‘ m ’ is the fading parameter of Nakagami-m channel and ‘ p ’ noise shaping parameter are the parameters used for the analysis. Therefore distinct values of ‘ p ’ and arbitrary value of ‘m’ are taken into consideration. MATLAB 15 software is used to simulate the results. All derived equations are represented in term of Meijer G function.

Figure 5.1 illustrates the performance of ABER derived in (5.11).In the Figure, a comparability of ABER has been presented between the proposed result having dual SC and the result of previous literatures with no diversity. BPSK modulation technique has been used over GGD noise with Nakagami-m fading channel. Numerical result has been presented at different values of noise shaping parameter namely ‘ p ’=1, 2 and 3 with fixed fading parameter at ‘ m ’ =2 in both cases (dual SC and no diversity).

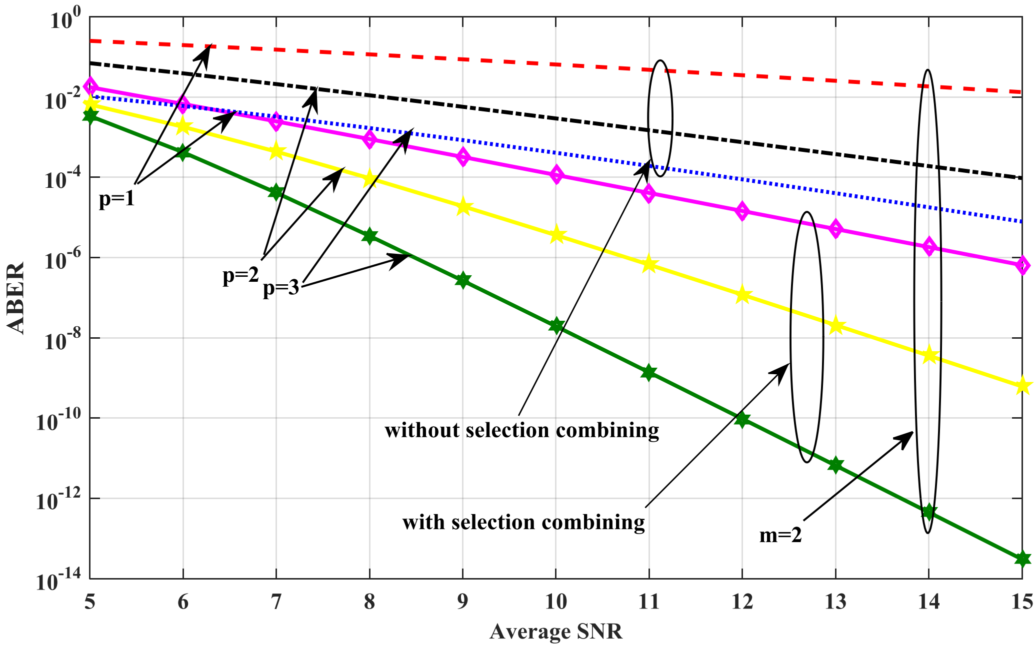

Figure 5.1 ABER for dual SC and no diversity over Nakagami-m fading subject to GGD noise for BPSK

Therefore, in both cases, ABER performance improved as the value of noise shaping parameter increased as expected with the considered SNR. At ‘ p ’ =1, value of ABER in no diversity case is 0.25 and in dual SC case its value is 0.01. However, reduction in the value of ABER in dual SC case indicate that amount of fading is less as compared with the no diversity case where amount of fading is high at ‘ p ’=1. It is to be noted that the same scenario has been followed for ‘ p ’=2 and 3. Therefore, it concludes that more reduction in ABER value shows less amount of fading in dual SC case comparison with no diversity case which validates our assumption.

Figure 5.2 presents the performance analysis of ABER by having a comparison between SC scheme and without SC scheme under Gaussian noise for BPSK. Numerical results have been presented at different values of fading parameter rnamely ‘ m ’ =0.5, 1.5 and 2 with fixed noise shaping parameter at p=2 (Gaussian noise) in both cases (dual SC and no diversity).

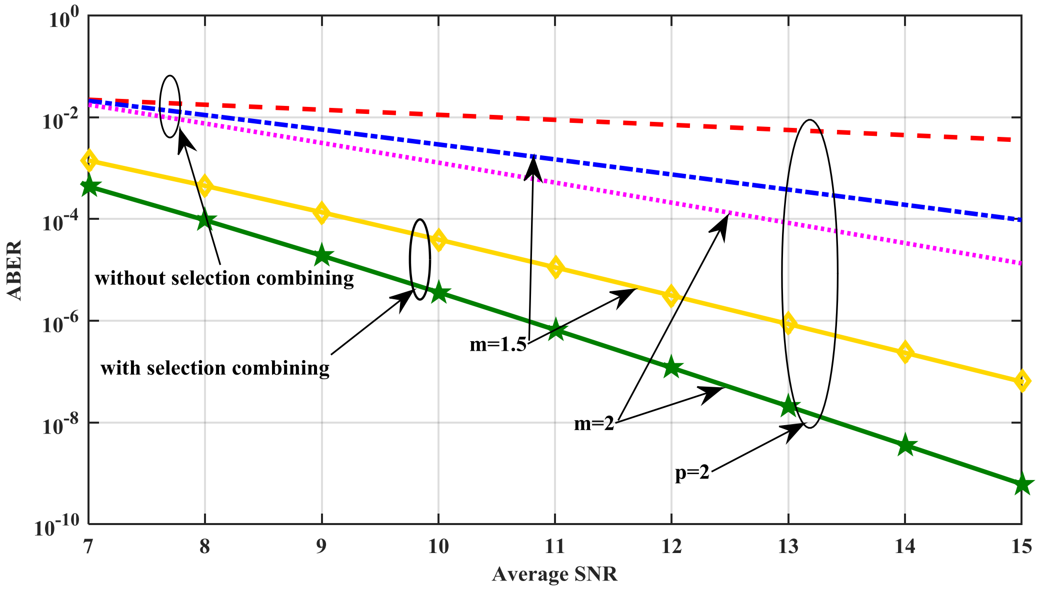

Figure 5.2 ABER for dual SC and no diversity over Nakagami-m fading subject to Gaussian noise for BPSK

In both cases, ABER performance improved as the value of fading parameter increased as expected. For low SNR region, the minimal drop in ABER can be observed for ‘ m ’ =0.5, 1.5 and 2 under no diversity scheme. As the value of SNR is increasing, the drop in ABER is discernible for the same value of ‘ m ’ i.e., 0.5, 1.5 and 2. However, the scenario of dual SC scheme is very much divergent for both low and high SNR value. The amount of reduction in the value of ABER in dual SC scenario is sharper and this indicates the better performance of dual SC scheme. At 8dB SNR, ABER value is 10^{-4} and$10^{-2}$for dual SC diversity scheme and no diversity scheme respectively for ‘ m ’ =1.5. Similarly but for large value of SNR e.g., 13, we can observe that ABER is still very close to 10^{-2} for no diversity scheme but for dual SC diversity scheme the value is close to 10^{-6}. Similarly, at ‘ m ’ =2 reduction in ABER is still more in dual SC case. Hence, the difference of amount of fading on the basis of ABER value indicates the advantage of having dual SC scheme as compare to no diversity scheme.

In Figure 5.3, the analysis of ABER is now obtained by using (5.11) for two values of noise shaping parameter p and two values of fading parameter m. This graph shows comparison with both parameter variation and represent which parameter value provide less ABER value for improved performance of the communication system in NC.

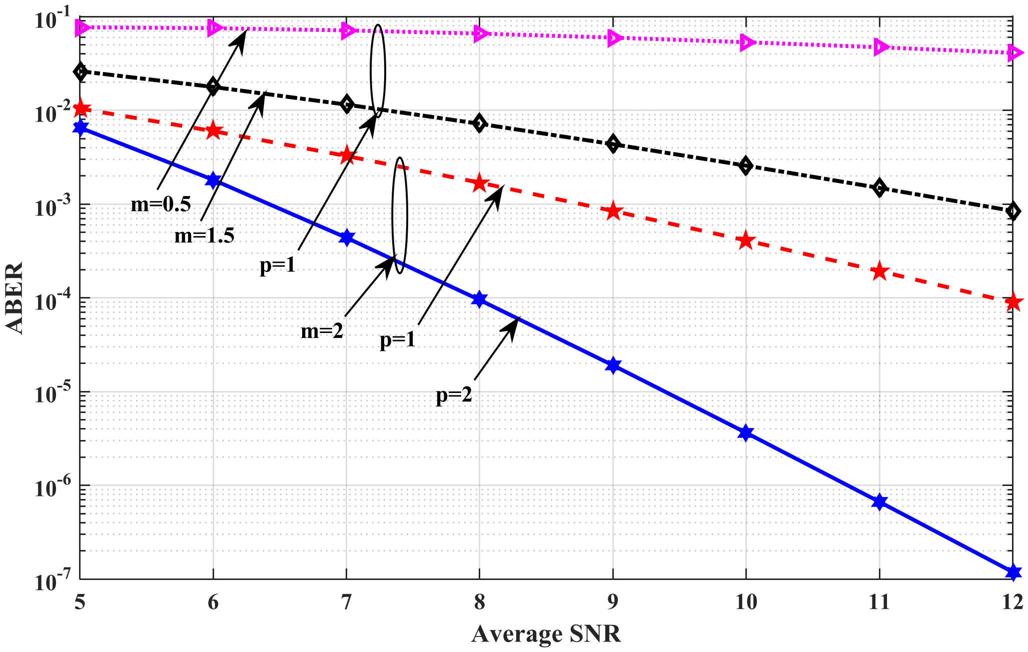

Figure 5.3 ABER for dual SC over Nakagami-m fading subject to Gaussian noise and Laplacian noise for BPSK

The system performance in terms of ABER has been improved at higher value of GGD noise parameter p and higher value of fading parameter m. According to graph, the value of ABER at Laplacian noise for ‘ m ’ =0.5 and 1.5 is close to 10^{-1}and10^{-2} at 7 dB SNR. Whereas, ‘ m ’ = 2 at 11 dB SNR give ABER value less than 10^{-6} for Gaussian noise and less than 10^{-3} for Laplacian noise. It indicates that at Laplacian noise system performance is improved at higher value of m. But when graph is plot for both Laplacian and Gaussian noise at higher value of ‘ m ’ i.e. ‘ m ’ =2 then the value of ABER is better for Gaussian noise. It concludes that for less value of ‘ m ’ =1.5 error dominates by fading but as the value of‘ m ’ =2 is increases then due to presence of additive noise, error tends to be more. Thus, use of GGD noise is best fitted for analysis of performance in EMNC-based BAN for NC.

Figure 5.4 illustrates the comparison between proposed results with diversity and literature result without diversity. Special case of MG fading channel i.e. Nakagami-m fading channel for M-PAM modulation technique over Laplacian noise under dual SC has been considered.

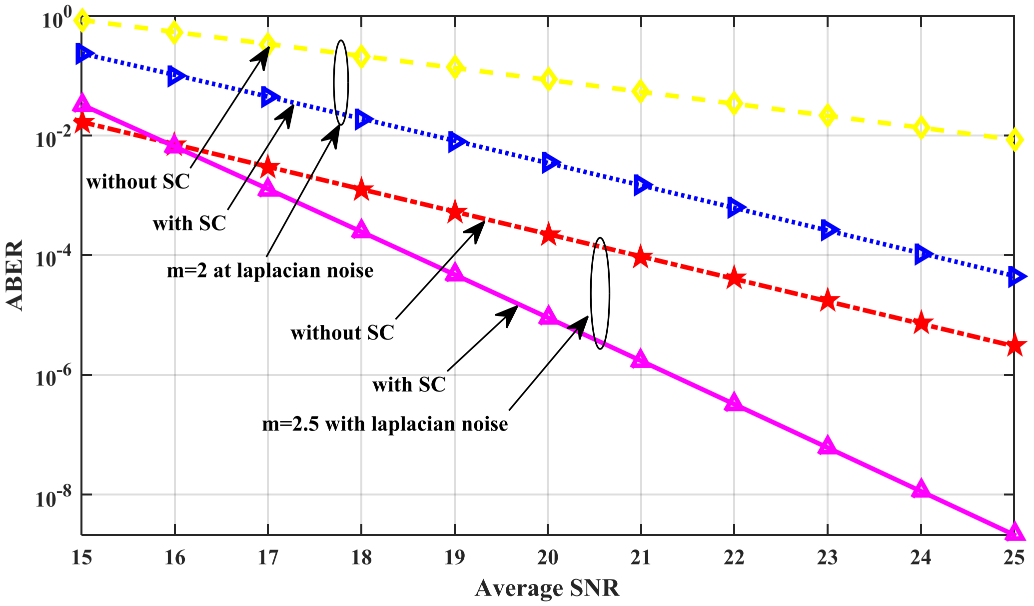

Figure 5.4 ABER for dual SC and no diversity over Nakagami-m fading subject to Laplacian noise for 16-PAM

Numerical result is indicated at varying fading parameter namely 'm' =2 and 2.5 over Laplacian noise. Graph shows that at 'm' =2 for Laplacian noise the difference in ABER value reduction is not more for low SNR region (17 dB) in both cases. But as the SNR range is increasing, the difference in ABER value reduction is more in dual SC case in comparison with no diversity case. However, for same noise (Laplacian noise) with 'm' =2.5, ABER value for both cases are exactly equal at 16 dB SNR , whereas at 23 dB SNR, the ABER value for dual SC case is less than 10^{-7} and less than 10^{-4} for no SC case. Therefore, a complete observation concludes that the amount of fading in dual SC case is much less than in no diversity case. Moreover, this condition is valid on noise also since GGD noise has been considered and proves their presence successful. Reduction in fading is more in dual SC case shows the performance of system is improved more with the addition of diversity.

Figure 5.5 shows the ABER curves of 32-PAM modulation technique over GGD noise with Nakagami-m fading channel under dual SC diversity scheme. Results have been presented as a function of average SNR at different noise shaping parameter value with fixed fading parameter m.

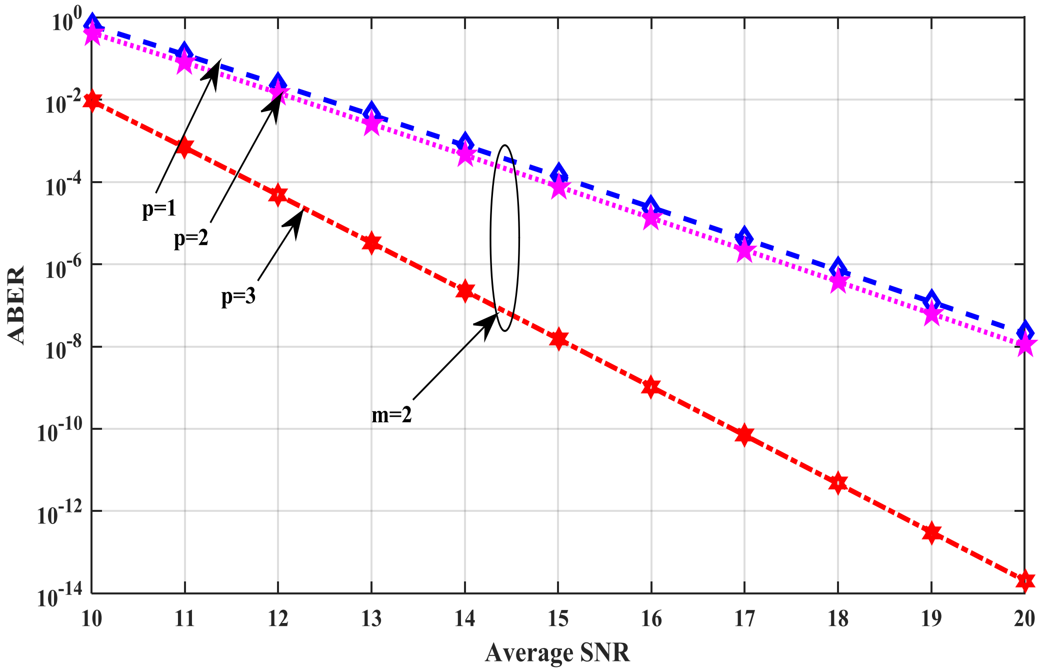

Figure 5.5 ABER for dual SC subject to GGD noise for 32-PAM

According to plot, reduction in ABER when noise value is converted from Laplacian noise to Gaussian noise is very negligible in value at 'm' =2 means reduction in fading severity is also less. However, as the value of p is increased from 2 to 3, means at 12 dB SNR the ABER value is less than 10^{-4} but at 17 dB, this value is increased and reached at 10^{-10}. This large and sharp reduction in the value of ABER is best for achieving best results regarding communication which is expected. As ABER is less, so the amount of fading is also less. So at 'p' =3 fading is less compared with 'p' =1 and 2. Fading severity is depending on the value of GGD noise parameter and fading parameter. This stated statement is true for wireless communication and nano communication is also a very important part of wireless communication. Therefore, the statement is also applicable in NC.

Figure 5.6 illustrates the performance of system in terms of ABER which is derived in 5.14 with distinct values of fading parameter at Laplacian noise.

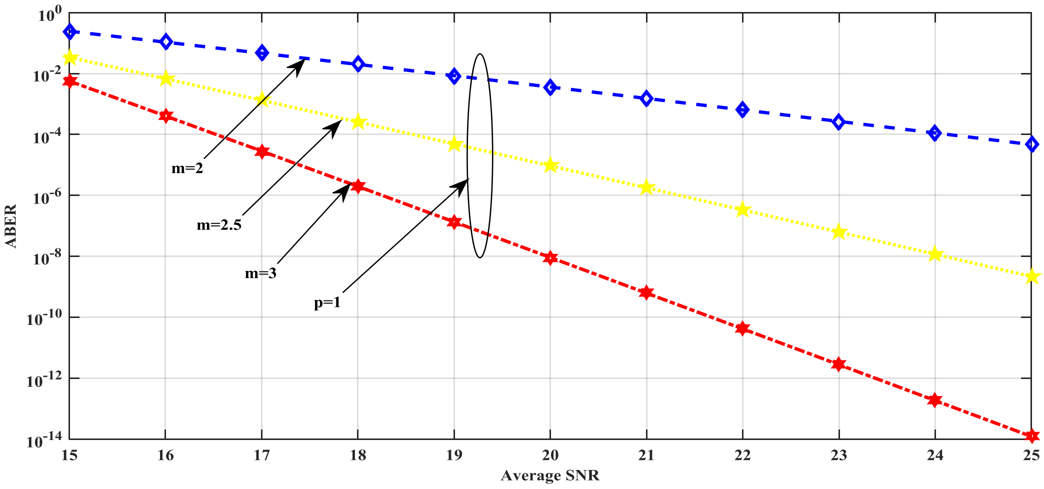

Figure 5.6 ABER for dual SC over Nakagami-m fading subject to Laplacian noise for 16-PAM

Above figure shows ABER curves for 16-PAM under the effect of Laplacian noise with dual SC for Nakagami-m fading channel with ' m ' =2, 2.5 and 3 at Laplacian noise. In graph at low SNR region (15dB-18dB), decrement in the value of ABER is less which means here fading influence the error and increase its effect. At high SNR region (19dB-25dB), ABER value reduction is more means in this case the effect of fading is also getting reduced. This will improve the performance of our system by reducing the severity fading for our system with the use of diversity combining.

Figure 5.3.7 depicts the ABER as a function of Average SNR Per symbol E_T/σ^2 for Laplacian noise with 16-QAM modulation technique. Distinct value of ' m ' has been chosen for the analysis of fading severity effect. Result is presented by using equation (5.25).

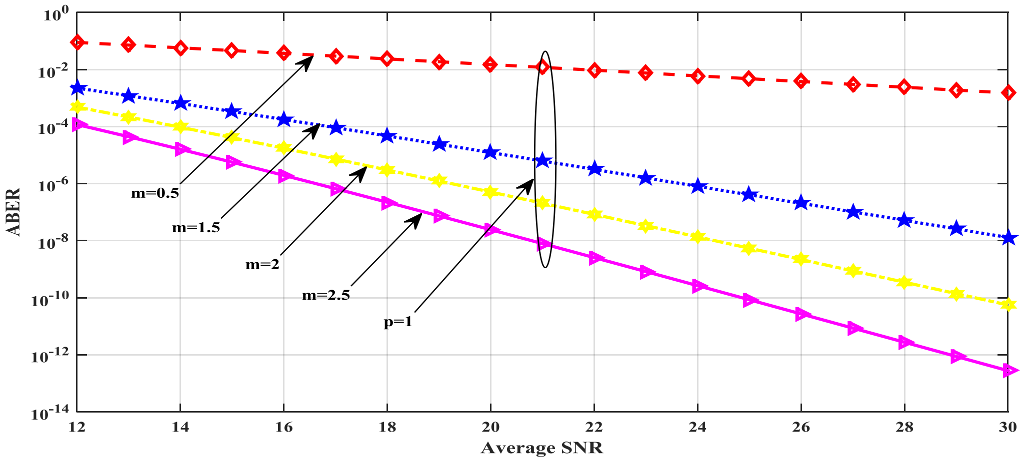

Figure 5.7 ABER for dual SC over Nakagami-m fading subject to Laplacian noise for 16-QAM

At 14 dB, ABER value is approximately equal to 10^{-1} and at 24 dB it is 10^{-2} for ' m ' =0.5. Whereas, ABER value for ' m ' = 1.5 at same SNR values are 10^{-3} and 10^{-6} , for ' m ' = 2 are 10^{-4} and 10^{-8} .

Similarly, for ‘ m ’ = 2.5 ABER values for same SNR are 10^{-5} and 10^{-10}. It means reduction in ABER is less for small value of fading parameter and reduction in ABER is less means at that time severity of fading for system is more. As the value of m is increased from 1.5 to 2 to 2.5, ABER value is decreasing with constant amount with sharp reduction. System performance is improved with the help of this graph because as the value of ‘ m ’ is increased, ABER gets reduced which is required for improved system performance.

In Figure 5.3.8, ABER curve for GGD noise with Nakagami-m fading under dual SC for four different values of M with special case of GGD noise (Laplacian noise) at ‘ m ’= 2 are shown.

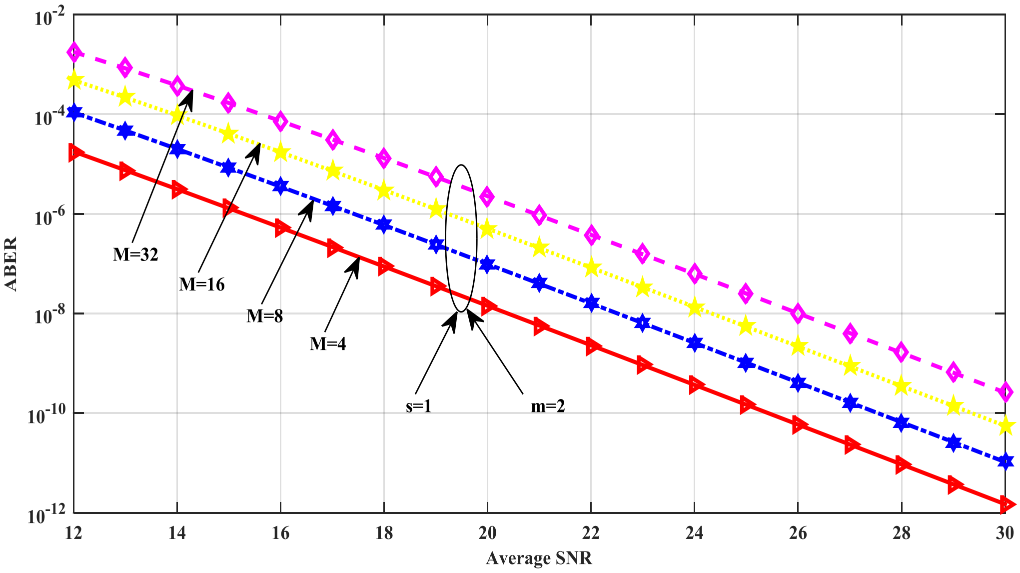

Figure 5.8 ABER for dual SC over Nakagami-m fading subject to Laplacian noise for M-QAM

It is observed that variation in ABER is almost same means constant effect of fading is shown. As the constellation value is less dense, we received smaller ABER value. As M is getting increased like M=4 to 8 to 16 to 32 the ABER value is also getting increased. It indicates that at less value of M ABER provide better result and the effect of fading is also lesser in that case. As the M increased, ABER also increased and fading severity also increased.

5.4 PERFORMANCE IMPROVEMENT TABLES FOR MG

Table 5.1 comparison between dual SC diversity and no diversity for BPSK

Parameters	values	Existing ABER	Proposed ABER	Improvements
‘ p ’ GGD noise shape parameter varied at =2 ‘ m ’	‘ p ’ =1	0.25	0.01	0.24
	‘ p ’ =2	0.124	0.006	0.118
	‘ p ’ =3	0.0236	0.0038	0.0198
‘ m ’fading Parameter Varied at	‘ m ’= 1.5	0.03734	0.001416	0.0359

Above table clearly presents the advantage of using dual SC diversity scheme in the form of reduction in the value of ABER. Also, as ‘ p ’ is increases then ABER value is decreases. Similarly for ‘ m ’=1.5, reduction is more in ABER value for proposed result than existing result.

Table 5.2 Comparison between dual SC diversity and no diversity for M-PAM

Parameters	values	Existing ABER	Proposed ABER	Improvements
‘m’ fading Parameter Varied at ‘ p ’ =2	‘ m ’ = 2	0.857	0.237	0.62
	‘ m ’= 2.5	0.0071	0.00654	0.00056

In M-PAM case, reduction for ‘ m ’=2 is less, means fading is more in this case. Whereas, for ‘ m ’=2.5 reduction in ABER is more means fading in ‘ m ’=2.5 case is less.

5.5 SUMMARY

Nano communication is applicable for various types of areas such as medical, environmental, military food management etc. In NC, medium is either EMNC or MNC for communication, hence in this thesis work EMNC-based BAN under CM1 scenario is used. Analysis of system performance through BER, capacity is a tedious task under CM1senario due to the presence of shadowing and fading in CM1 model. However, the modeling of fading and shadowing can be done by using composite fading channel models. Therefore, in this chapter MG fading channel model has been considered for modeling purpose. Modeling of noise is also required because of its occurrence at the time of transmission. GGD noise distribution has been used to model noise in EMNC. Also the diversity technique is helpful for receiving signal with very less amount of degradation in information. Hence, optimized SC diversity scheme has been considered to mitigate the effect of fading in NC. A new model for evaluating BER under SC over GGD noise with proposed MG has been developed in thesis work. In this chapter comparison results between proposed model and literature model via BER at different modulation schemes has been presented. In BPSK and M-PAM, comparison between existing BER and proposed BER for different fading parameter ‘m’ has been shown. This comparison concludes that as the value of fading parameter is increased its ABER gets reduced but presence of diversity in proposed model reduce fading severity in large in amount in comparison with existing model. Similarly, as the value of noise shaping parameter is increased its ABER also gets reduced in both the models but more reduction of ABER is shown in proposed model. Hence we conclude that use of diversity proves a better solution for analyzing the system performance in EMNC-based BAN under CM1 scenario.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

Recently, a new era of communication has been explored by nanotechnology known as Nano communication (NC). Various important applications for NC have been served from environment (air pollution control) to medical (drug delivery system, health monitoring etc.) to military (NBC defense). The work has been started by the researchers for making this application applicable in real time. In real time communication system; the most considerable factor which needs more attention is impairments namely fading, noise and interference. Therefore, this thesis presents a novel model for the analysis of system performance in the presence of noise and fading for NC system. System analysis in NC has been performed in term of ABER for EMNC-based BAN under CM1 scenario. However, WG and MG shadowed fading channels are considered to model fading and shadowing. Further, a generic noise distribution known as GGD has been used as a noise model. This distribution consists of various noises and AIGN is presented as a special case of GGD which is also used to model noise in EMNC. Moreover, SC diversity scheme has also been considered for mitigating the effects of fading and shadowing in NC for CM1 scenario.

For the calculation of ABER under WG and MG fading channel at different modulation techniques over GGD noise, PDF under dual SC scheme has been derived. Further, closed form expressions under same scenario for ABER evaluation has been proposed. In numerical analysis, parameters used are ‘α’, ‘β’, ‘p’ and ‘m’ represent shadowing, fading, noise shaping, Nakagami fading parameter for WG fading channel and MG fading channel respectively. ‘p’ is a noise shaping parameter represents and p =1 represent Laplacian noise, ‘p’ = 2 converted into Gaussian noise. The effect of noise and fading on ABER is varied as the value of fading and noise shaping parameter changes. Fading severity is reduced with the increment in the value of ‘α’, ‘β’, ‘p’ and ‘m’ and error is influenced by noise.

ABER over WG shadowed fading model has been calculated by fixing two parameters and varying the third parameter for BPSK and M-PAM. Comparison between proposed results under dual SC and existing results with no SC has also been presented in term of ABER. This comparison shows that at 19 dB SNR the ABER for proposed result is 10^{-2}. But ABER for existing result with no SC case at the same SNR value is close to 10^{-1}. Thus, with comparison it is observed that our expectation with using the diversity scheme has been fulfilled. ABER for M-PAM is also shown in which at 20 dB SNR value, ABER for ‘p’ = 1 is less than 10^{-2}. As the value is increased from 2 to 3 to 4, ABER gets reduced. At‘ p ’ = 4 ABER is 10^{-4} at same SNR value. This type of reduction in ABER with increased value is expected for reducing the fading and noise effect.

MG shadowed fading channel model is a most generic model and can be applied for various composite fading channel models. In this thesis, Nakagami-m fading channel has been considered for the analysis of ABER at BPSK, M-PAM and M-QAM under same consideration. For numerical analysis, arbitrary values of‘ m ’ and distinct value of ‘ p ’ has been used. According to comparison results for BPSK in MG case, for ‘ p ’ = 2 ABER at 8 dB in dual SC proposed result is 10^{-4} but in no SC case ABER is 10^{-2}. Similar Trend has been followed by dual SC for other values of ‘ p ’ in ABER value reduction at ‘ m ’ =2. Further, comparison result for M-PAM has been also presented. Compared results validate our assumption. Moreover, ABER for M-QAM has been calculated for varying M also.

6.2 FUTURE SCOPE:

In this thesis work, a novel model for analysis of ABER over composite fading channel has been proposed. This proposed model has been performed for different modulation techniques with dual SC scheme under GGD noise for NC system. However, the open research problems of this proposed work are as follows.

1. Suitable composite fading channel other than WG and MG may be considered for the analysis of ABER for NC.
2. To deal with the consequences of fading and noise various diversity schemes like EGC, MRC, GSC can also be used as an impairment mitigating technique in NC.
3. ABER analysis may be performed on other modulation techniques by deriving the CEP for considered modulation scheme over GGD noise.
4. CM1 under different scenarios rather than SC1 for EMNC-based BAN may also consider for diminishing the effect of fading and shadowing.
5. Different performance analysis parameters like capacity other than ABER may be analyzed in NC.
6. For establishing the complete infrastructure of NC, concept similar to frequency reuse may be used.

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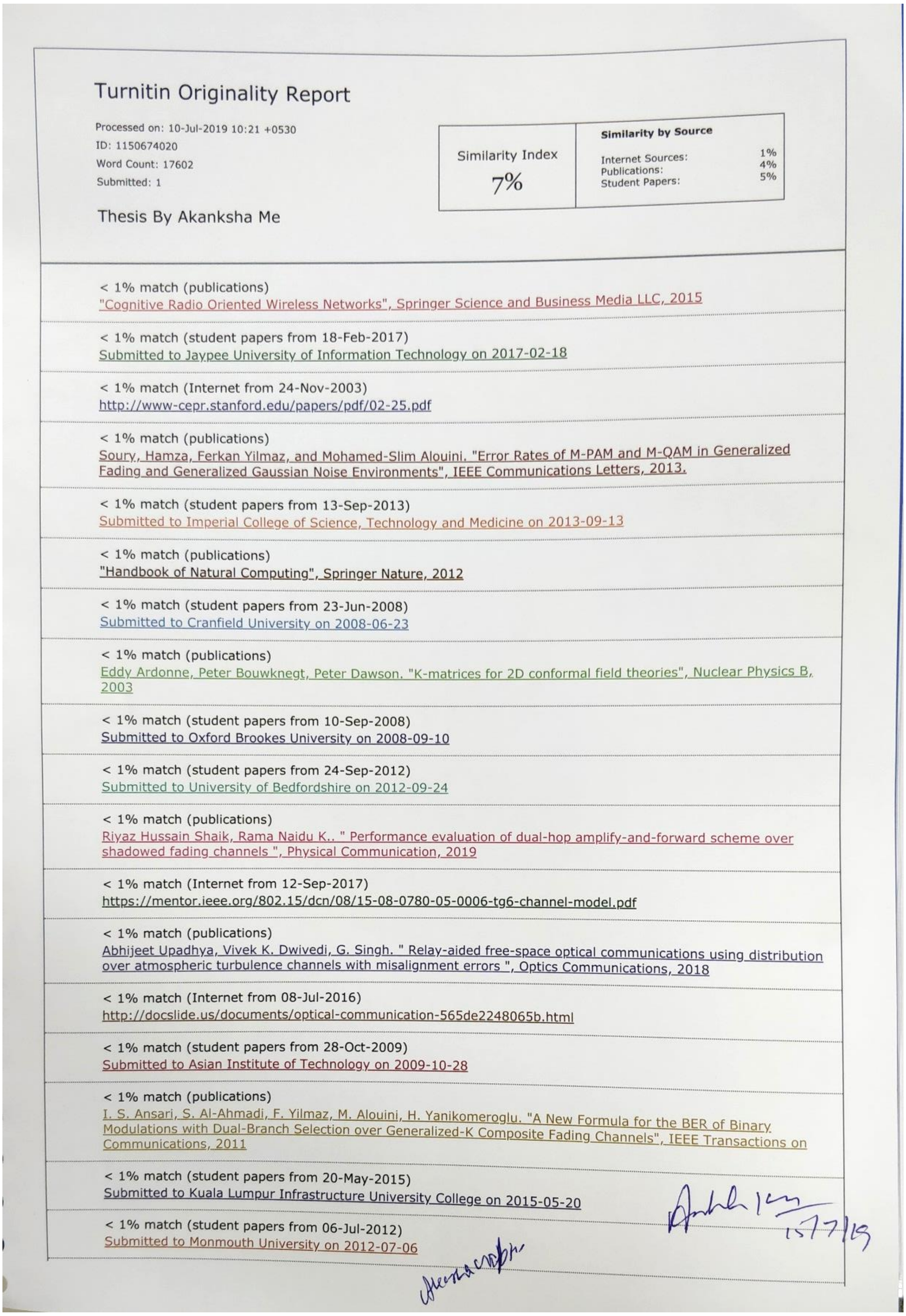

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