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The Analytical Approach to Evaluate the Bit Error Rate Performance of PLC System in Presence of Cyclostationary Non-White Gaussian Noise

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ABSTRACT

In a Powerline Communication (PLC) system, improper connections of associated hardwires can lead to the generation of unwanted RF signals, overriding the transmitted signal and producing undesired RF spurious signals. Noise in powerlines also arises from the corona effect, voltage impulses, and arcs occurring in transmission and distribution lines, significantly compromising the integrity of the PLC network. Analysis indicates that powerline noise exhibits a non-white cyclostationary characteristic. Due to its severity, PLC noise is categorized primarily as background noise and impulsive noise. This paper evaluates the characteristics of a powerline network under severe noisy conditions, particularly focusing on Cyclostationary Non-White Additive Gaussian Noise (CNWAGN) across broadband and narrow frequency communication channels. Accordingly, an analytical model is developed to specifically examine the bit error rate (BER) in environments affected by non-white additive Gaussian noise. BER and receiver sensitivity are also assessed for various bit rates using MATLAB simulations, demonstrating performance in terms of BER. This analytical model provides a straightforward method to evaluate results across different bit error rates in frequency-dependent and independent scenarios, surpassing traditional approaches. It proves highly effective in assessing Powerline Communication System performance, with analytically derived outcomes closely aligning with simulation results.

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1. NOMENCLATURE

Tx	Transmitter
CNWAGN	Cyclostationary non-white Additive Gaussian noise
NPIN	Non-periodic impulsive noise
PSD	Power Spectral Density
S(t)	Transmitted signal
R(t)	Received signal
Z_{L11}…. ZL_{1n}	Branch impedances of PLC system
M_T	Total number of distributed nodes
Z_s	Source impedance

Z_R	Load impedance
Z_{LMTm}, Z_{LMTn}	Transmission factor at the referenced load m, and n respectively
δ	Small duration of time
A_c	Peak amplitude of the carrier
f_c	Carrier frequencies
ø	Random carrier phase
r(t)	Received signal
n(t)	Noise component of the received signal
$P(n(iT_s))$	Probability density function (PDF) at time t = iTs
σ^2 (t)	Instantaneous variance of the cyclostationary noise
γ	Normalization constant
E(.)	Ensemble average
ρ	Normalized value to get unity variance
θ_l and nl	Parameters of noise characteristic
A_l, B_l	Fourier constants
LPF	Low pass filter
$\alpha(f)$	PSD of the non-white powerline
a	Power line constant (taken as 1.2 x 10^{-5})

2. INTRODUCTION

Noise is the redundant signal generated electrically or electromagnetically during signal transmission, rendering the desired signal erratic and compromising the quality of received data or signals. Sources of noise are diverse, including lightning, radio waves, nearby current-carrying cables, and faulty connections. In modern Power Line Communication, noise poses a significant challenge, disrupting radio, television, cable TV, and internet services. Radio communications, especially amateur radio, are particularly susceptible to disruption. Specialized services such as those used by the military and police, operating within the RF band, can experience severe interference [1-2]. Primarily, arcing or electrical sparks within hardware are the leading causes of power line disturbances [3-4]. Hostile noises affecting PLC environments are categorized as, (a) Narrow-band Noise (NBN), (b) Coloured-background Noise (CBN), (c) Synchronous and asynchronous periodic-impulsive noise, and (d) Non-periodic impulsive noise (NPIN) [4-5].

In this analysis, cyclostationary non-white Additive Gaussian noise (CNWAGN) is regarded as a composite of two distinct types of noise: narrowband noise and colored background noise.

A Cyclostationary process is characterized by statistical properties that fluctuate periodically over time. It is represented using mathematical models and is widely employed in modern signal communication systems to ensure reliable transmission in hostile environments [5]. The term 'Gaussian distribution' originated from the work of Carl Friedrich Gauss in 1809, where he introduced parameters for the exponential distribution of quantities observed in astronomical studies. Gaussian noise refers to the probability density function (pdf) that follows a Gaussian distribution, basically which is the probability of a certain signal. While, white noise denotes uniform signal power distribution over time intervals, possess a fixed Power Spectral Density (PSD) value across all frequencies.

The non-white noise process is to be converted to white during processing. With non-white noise, the spectral shape of the noise is initially assessed and then spread across the entire spectrum. By employing a pre-whitening filter in the modeling phase, such signals can be made white.

Cyclostationary processes exhibit cyclical variations over time and possess statistical properties [6]. When multiple interleaved stationary processes combine, they form a cyclostationary process. Circuits having intermittent operating nature normally generate noise of Cyclostationary characteristics. Noises generated by various sources are modulated by the time dependent operating circuit at different point, and hence the transfer functions. Consequently, cyclostationary noise is produced at the output.

Background noise refers to extraneous contaminating signals that cannot be distinguished from the desired signal. In the frequency domain, background noise exhibits non-uniform distribution, often referred to as colored noise. This type of noise is more pronounced in low-frequency signals compared to higher frequencies. One distinctive feature of background noise is its non-white nature across the frequency band, persistently override power line signal. The power spectral density (PSD) of this noise varies with frequency, decreasing as frequency increases. For instance, between 9-95 kHz, the PSD decreases by approximately 20-25 dB per decade indoors and 35 dB per decade outdoors [7-8]. As a whole, background noise power decreases for increasing frequencies.

Noise emanating from computers, dimmers, hair dryers, and similar devices is superimposed together to produces colored background noise, which causes significant disturbances within the 0-100 MHz frequency range. This colored background noise represents the cumulative effect of various low-power noise sources, each contributing a small power spectral density (PSD). The power spectral density varies over time, spanning minutes and even hours.

Typically, narrowband noise exists as sine wave signals modulated in amplitude, originating from broadcasting stations and affecting medium and shortwave frequencies.

Recently, numerous researchers have made significant contributions to the noise modeling of powerline communication (PLC) systems. For instance, the mitigation of the cyclostationary impulsive model using Orthogonal Frequency-Division Multiplexing (OFDM) and Frequency Shift (FRESH) filtering has been proposed in [20]. The narrowband OFDM PLC noise has been analyzed through a data measurement method in [22]. Furthermore, a technique for mitigating cyclostationary impulsive noise in narrowband powerline communications using FRESH filtering is discussed in [23]. Adaptive Nonlinear Differential Limiters (ANDL) have been employed to address cyclostationary impulsive and asynchronous noise in PLCs, as presented in [24]. The cyclostationary model has been examined using hybrid analysis with MIMO-OFDM and WiNPLC software in [25]. In [26], PLC impulsive noise has been analyzed utilizing the Middleton Class A model. Additionally, receive diversity techniques have been proposed to enhance PLC impulsive noise performance in [10], while the mitigation of cyclostationary noise in PLC is further explored using FRESH filters and direct-sequence spread spectrum (DSSS) receivers in [26].

In this research, we have made an analysis to model the impulsive noise and Cyclostationary Non-White Additive Gaussian Noise both in broadband and narrow band communication channel which is a timely research demand of PLC. There are many works on BER performance evaluation of PLC, but none has shown the receiver sensitivity across varying bit error rate of the system which is the uniqueness of this work.

3. SYSTEM BLOCK DIAGRAM

For this analysis, the block diagram of a PLC network affected by various types of noise is shown in the following figure (Fig. 1). From the Tx (transmitter), once the transmitted signal, S(t) enters into the PLC channel, the transmitted signal becomes spurious signal due to addition of various types of noises as shown. In the receiver, diversity reception is considered via numerous receiving ports. The received signal R(t) is processed through different modulation techniques to get rid of these noises.

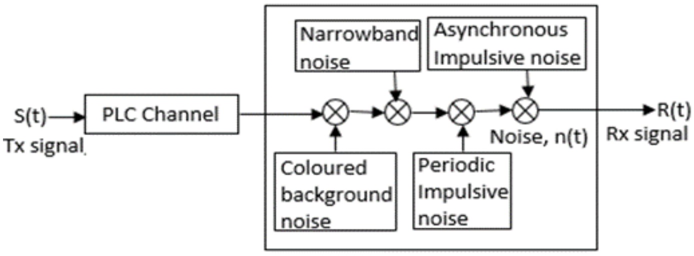

Figure 1. Noise on power line communication system receiver.

4. NOISE MODELING TECHNIQUES

4.1. Background noise

Depending on the type of analysis, two approaches are followed while modeling the noise, namely; frequency domain approach and time-domain approach. In the first approach, i.e., frequency domain case, noise measurement technique in the frequency spectrum is adopted, whereas the real-valued noise waveform is measured over time in time domain approach. The impulsive noise is represented both in frequency and time domain but background noise is primarily represented in the frequency domain. Again, in frequency domain for modeling the background noise two methods are followed, such as, spectrum fitting [10, 13], and the other is the measured noise power spectral density (PSD) or voltage spectrum density (VSD) modeling [14]. Though it covers the whole spectrum of noise, yet at individual frequency, it is unable to present any details of the noise random behavior. Method of statistical analysis is followed for modeling the variation of background noise and variation in individual frequency spectrum at a particular probability density function (PDF) [11, 12].

In addition to the models described above, numerous researchers have projected newer techniques to analyze background noise and the impulsive noise using the model of cyclostationary noise [15], [17]. Numerous Studies show that considerable amount of noise in powerline varies keeping synchronism with half of the frequency of the supply mains. In broadband system, to evaluate the average performance of a powerline network, frequency-domain approach has been followed. Here, statistical study method is used to model background noise whereas noise-bandwidth measurement technique is used to characterize the impulsive noise in different electrical/electronic utility appliances [15].

4.2. Impulse Noise:

Impulse noise is a type of disturbance marked by abrupt, sharp sounds or brief bursts of noise. Defined by its short duration and high intensity, it often manifests as distinct pulses within a signal. This type of noise can arise from several sources, including electrical interference, voltage surges, or physical disruptions in a transmission medium. The ideal shape of impulsive noise is shown in Fig.2.

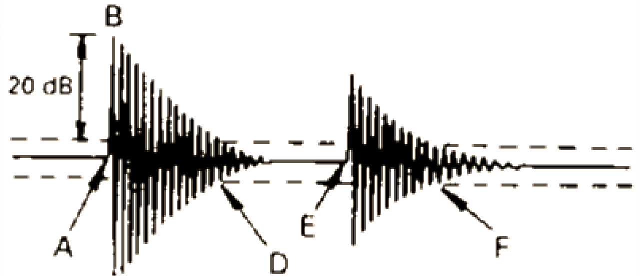

Figure 2. Shape of Ideal Impulsive Noise

4.3. Types of Impulse Noise

Impulse noise can be classified into three categories:

- High pulse sound
- High energy impulse sound
- Typical impulse sound

(1) **High Pulse Sound**

High pulse sounds are distinguished by their sudden onset and elevated intensity. These brief bursts of sound with high energy levels often produce a startling effect due to their abruptness and loudness.

(2) **High Energy Impulse Sound**

High energy impulse sounds usually involve a significant release of energy. These sounds are not only loud but also involve the rapid discharge of immense energy, producing intense pressure waves that can damage nearby structures or pose risks to human safety, especially when close to the source.

(2) **Typical Impulse Sound**

Typical impulse sounds are common occurrences marked by their sudden, brief nature. They produce short bursts of sound with moderate intensity and can be disruptive and annoying, particularly in residential or office settings. However, they generally pose minimal risk to hearing health or physical safety compared to other types.

4.4. Modeling of background noise

The background noise is modeled into two categories as follows.

- T. Esmailian Model

This model is proposed by T. Esmailian [16]. This model describes mathematically the Power Spectral Density (PSD) of background noise. This model is based on the assumption that in frequency band, the distribution of background noise is non-uniform. It is a coloured noise, significantly present at low frequency and less found in high frequency. Background noise has a time dependent power spectral density (PSD).

- Mixed Model of Nakagami distribution

Powerline Communication system cannot be represented as additive white Gaussian Noise (AWGN) channels. In a PLC, there are many complex issues like, presence of different types of noises, i.e., impulsive noise background noise, various types of interferences which make the propagation issue more cumbersome. For powerline the residential buildings, household electrical/electronic goods, adjacent line, plugging systems, etc. are the prime sources that generate background noise. A thorough study for the characterization of background noise in a PLC system confirms that the amplitude of noise pdf (probability density function) in time domain found to be similar to the distribution of Nakagami-m function.

4.5. Impulsive noise model

Powerline channel experiences different impulsive noise impediments which originate bit/burst error during signal communication. The main causes are, different electrical connections including transformers, switch gears, switches used for industrial applications, etc. Noise model described by Middleton’s class-A is appropriate for use in conjunction with broadband power line communications (BPLC) channel models in impulsive noise environments. The summation of background noise and impulsive, independent identically distributed (i.i.d) variable along with class A noise probability density function (PDF) has been analyzed by D. Middleton in [17].

4.6. Cyclostationary noise

In this model, the PLC noise has been grouped in four types as follows:

(1) Continuous colored noise.
(2) Continuous tone jammers.
(3) Periodic impulses synchronous to mains, and
(4) Impulsive noise asynchronous to mains.

Noise having time variant characteristics was analyzed by Zimmermann and Dostert with partitioned-Markov chain model of several states [18]. For wide-band powerline communication, it is represented by Middleton class D model. Though, class (A), (B) and (C) are also present in the form of impulses of periodic nature. Therefore, a continuous noise is represented by a mathematical model is developed [14]. While communicating in broadband PLC channel, naturally it occupies the complete HF frequency-band, the line impedance is always dependent on frequency has to be catered. Conversely, it is assumed that the variation of line-impedance in narrowband is negligible i.e., it is independent of frequency.

Characteristics of PLC noise are considered as cyclostationary non-white Additive Gaussian (CNWAG) process [18, 19]. PLC noise has periodic characteristics with time period Tac/2; Tac denotes the AC mains time period. Thus, its amplitude characteristic is similar to Gaussian distribution. And hence, this PLC noise is supposed to be cyclostationary additive Gaussian noise (CAGN) having zero mean value. The variance of this noise is found to be synchronous to the main AC supply voltage.

The input data is used to modulate a sinusoidal carrier of frequency 0.3 MHz to 30 MHz using a binary phase shift keying modulator. The input of the modulator is fed to the PLC channel. The PLC network consists of lines, branches, nodes and junctions as shown in Fig. 3. Here, Z_{L11}.... ZL_{1n} are the branch impedances. n, m, M represent any branch number, any referenced (terminated) load, number of reflections (with total L number of reflections), d is any referenced node. M_T is the total number of distributed nodes (1..2.. d…M_T). Z_s is the source impedance, Z_R is load impedance. Z_{LMTm} and Z_{LMTn} are the transmission factor at the referenced load m, and n respectively. The output signal is corrupted by noise due to power line which is cyclostationary in nature. The received signal is detected and demodulated by a coherent BPSK demodulator and data decision is made.

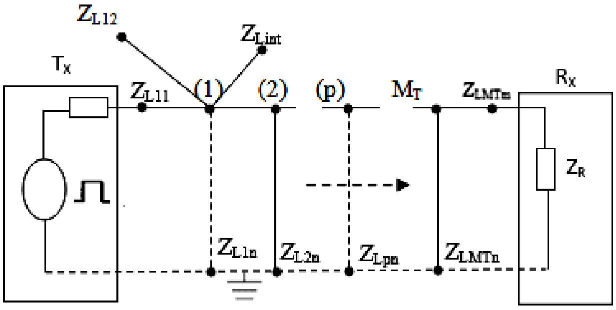

Figure 3. Power Line network showing Transmitter (T_X), Receiver (R_X), distributed branches and nodes.

5. SYSTEM ANALYSIS

Analysis of PLC system considering Cyclostationary noise: In this analysis it is assumed that for a small duration, i.e., t - δ ≥ t ≤ t + δ, the signal contains constant power. For such short span of time the transmitted signal considering BPSK is given by,

$$S(t) = A_C \, Cos(2\pi f_C \, t + \o) \tag{1}$$

where, A_C is the peak amplitude of the carrier, f_C is the carrier frequencies and ø represents random carrier phase. At the receiver, the signal is represented by,

$$r(t) = A_c e^{-\alpha d/2} Cos(2\pi f_c t + \phi) + n(t) \tag{2}$$

here, α represents the co-efficient of attenuation of power line, d is the transmission path length and n(t) represents the component of noise which represents the cyclostationary NWGN having zero mean value whose variance is synchronous to the main supply voltage. It’s probability density function (PDF) at time t = iTs is given by [16],

$$P(n(iT_s)) = \frac{1}{\sqrt{2\pi\sigma^2(iT_s)}}\exp\left[\frac{-n^2(iT_s)}{2\sigma^2(iT_s)}\right] \tag{3}$$

where, σ^2 (t) represents the instantaneous variance of the cyclostationary noise and can be defined as,

$$\sigma^2\ (t) = \gamma.\ E\ [n^2\ (t)] \tag{4}$$

where γ is a normalization constant and E(.) denotes ensemble average.

σ^2 (t) was assumed to be a periodic function, thus for normalized value of the waveform, the ensemble-average given above can be replaced by the instantaneous value of the average power in time period Tac/2. So, variance of n(t) representing the instantaneous power at $0 \le iTs \le Tac/2$, can be expressed by [17],

$$\begin{aligned}\sigma_m{}^2(iT_s) &= \frac{1}{2m}\sum_{j=0}^{2m-1}\eta^2\left[iTs + j\frac{T_{ac}}{2}\right] \\ &= \frac{\gamma}{2m}\sum_{j=0}^{2m-1}\rho^2\left[iTs + j\frac{T_{ac}}{2}\right]\end{aligned} \tag{5}$$

where m is an integer and number of noise samples is 2m, η is the sample vale of n(t) and ρ is the normalized value to get unity variance. Here the value of γ is obtained from equation (4) and ρ is obtained from the normalized value of the equation.

According to cyclostationary noise characteristics [17],

$$\underset{m\to 0}{Lt}\ \sigma_m{}^2(iT_s) = \sigma^2(iT_s) \tag{6}$$

It is simplified using sample-function and reduced to a few number of parameters. To do so, in this modeling an approximation of σ^2(t) is employed as follows:

$$\sigma^2(iT_s) = \sum_{l=0}^{L-1} A_l\ Sin\left|\left(\frac{2\pi}{T_{ac}}t + \theta_l\right)\right|^{nl} \tag{7}$$

here A_l, θ_l and nl are the parameters of noise characteristic and l = 0, 1, 2 ..... (L-1). Using Fourier analysis we get [14],

$$\sigma^2(iT_s) = \sum_{l=0}^{L-1} A_l\ Cos 2\pi\frac{2l}{T_{ac}}t + B_l\ Sin 2\pi\frac{2l}{T_{ac}}t \tag{8}$$

Where,

$$A_l = \begin{cases}\dfrac{1}{T_{ac}}\displaystyle\int_0^{\frac{T_{ac}}{2}}\sigma^2(t)dt; \quad for\ \ n = 0 \\ \dfrac{2}{T_{ac}}\displaystyle\int_0^{\frac{T_{ac}}{2}}\sigma^2(t)Cos 2\pi\frac{2l}{T_{ac}}tdt; \quad for\ \ n \neq 0\end{cases} \tag{9}$$

$$B_l = \frac{2}{T_{ac}}\int_0^{\frac{T_{ac}}{2}}\sigma^2(t)Sin 2\pi\frac{2l}{T_{ac}}tdt \tag{10}$$

The power P_n(t) is given by,

$$\begin{aligned}P_n(t) &= \frac{2}{T_{ac}}\int_0^{\frac{T_{ac}}{2}}\sum_{l=0}^{L-1} A_l\ Cos 2\pi\frac{2l}{T_{ac}}t\,dt \\ &+ \frac{2}{T_{ac}}\int_0^{\frac{T_{ac}}{2}} B_l\ Sin 2\pi\frac{2l}{T_{ac}}tdt\end{aligned} \tag{11}$$

$$or,\quad P_n(t) = \frac{2}{T_{ac}} \int_0^{\frac{T_{ac}}{2}} \sum_{l=0}^{L-1} A_l \left[Sin2\pi \frac{2l}{T_{ac}} t . \frac{T_{ac}}{4\pi l} \right]_{t=0}^{\frac{T_{ac}}{2}} \tag{12}$$

$$+ \frac{2}{T_{ac}} \int_0^{\frac{T_{ac}}{2}} \sum_{l=0}^{L-1} B_l \left[-Cos2\pi \frac{2l}{T_{ac}} t . \frac{T_{ac}}{4\pi l} \right]_{t=0}^{\frac{T_{ac}}{2}}$$

$$P_n(t) = \sum_{l=0}^{L-1} \frac{A_l}{2\pi l} \left[Sin2\pi l \right] - \sum_{l=0}^{L-1} \frac{B_l}{2\pi l} \left[Cos2\pi l - 1 \right] \tag{13}$$

where P$_n$ denotes the mean variance power of noise in one-bit period and can be represented by σ^2. The received signal power in the period $t - \delta \geq t \leq t + \delta$ is given by [6],

$$P_s = \frac{e^{-\alpha d}}{2\delta} \int_{t_0-\delta}^{t_0+\delta} S^2(t) dt \tag{14}$$

In the LPF (Low pass filter) receiver output the SNR (signal to noise ratio) is given by [14],

$$SNR = P_s / P_n(t) \tag{15}$$

$$SNR = \frac{P_s}{\sum_{l=0}^{L-1} \frac{A_l}{2\pi l} \left[Sin2\pi l \right] - \sum_{l=0}^{L-1} \frac{B_l}{2\pi l} \left[Cos2\pi l - 1 \right]} \tag{16}$$

$$SNR = \frac{\frac{e^{-\alpha d}}{2\delta} \int_{t_0-\delta}^{t_0+\delta} S^2(t) dt}{\sum_{l=0}^{L-1} \frac{A_l}{2\pi l} \left[Sin2\pi l \right] - \sum_{l=0}^{L-1} \frac{B_l}{2\pi l} \left[Cos2\pi l - 1 \right]} \tag{17}$$

Now the BER will be,

$$BER = 0.5 erfc \left[\frac{\frac{e^{-\alpha d}}{2\delta} \int_{t_0-\delta}^{t_0+\delta} S^2(t) dt}{\sum_{l=0}^{L-1} \frac{A_l}{2\pi l} \left[Sin2\pi l \right] - \sum_{l=0}^{L-1} \frac{B_l}{2\pi l} \left[Cos2\pi l - 1 \right]} \right]^{\frac{1}{2}} \tag{18}$$

For frequency independent case, A$_l$ and B$_l$ are calculated using σ^2 (t) given by equations (9, 10). For frequency dependent case, A$_l$ and B$_l$ are calculated using,

$$\Sigma^2 (t, f) = \sigma^2 (t)\, \alpha\, (f) \tag{19}$$

where $\alpha(f)$ denotes the PSD of the non-white powerline noise and can be expressed as [16],

$$\alpha(f) = \frac{a}{2} \exp\left(-a |f| \right) \tag{20}$$

where '*a*' is a power line constant. In this analysis, we have considered value of '*a*' as 1.2×10^{-5} [16].

6. VALIDATION OF THE DEVELOPED MODEL

This section presents validation process of the developed model. Validation is performed with the results of the model developed in the previous section and a comparison is made with the results obtained in the papers sited in the literature review. Considering a real system, our obtained results of the proposed model are compared through circuit simulation.

In this research work, bit error rate is obtained through MATLAB simulation. The results are compared with some novel works of the same field. It is very encouraging that in most cases our work represents improve performance. Table1 shows the comparison of the results as follows.

Table 1. Results comparison obtained from various research works.

Serial no.	Ref No.	Obtained result, SNR(dB)	Result of this research	Remarks
1	[20]	24 at BER 10^{-5}	22 dB (fig.3)	Improved results
2	[21]	23.8 (at BER 10^{-2} ~ 10^{-3}) (for 100Kbps)	24 dB (fig.6)	Similar results
3	[22]	21 at BER 10^{-4}	15.5, 16.5 and 17 dB (fig.5)	Improved performance
4	[23]	35 at BER 10^{-4}	30, 32 and 35 dB (fig.4)	Improved performance
5	[24]	20~30 at BER 10^{-2}	22 dB (fig.3)	Improved performance
6	[25]	18 at BER 10^{-2}	17.5 to 18.5dB (fig.5)	Similar results

The developed model of this paper is also applied into the same system considering the same parameters and the results is compared with the results obtained from the simulation of the circuit using MATLAB. It is clearly seen that the obtained result from the developed model is very much near to the simulation result and the magnitude of the average difference is found to be negligible.

7. RESEARCH DATA

Based on the analytical model illustrated in section 4, we have evaluated the performance of a power line communication channel in terms of BER with cyclostationary noise considering non-white power spectral density (PSD). Fig. 4 through Fig. 8 are the presentation of the results of different parameters used for the system analysis is shown in Table 2 [16].

Table 2. Data used for this research works.

Serial No.	l	A_l	B_l	R_b	a
1	0	1.0	0	1 Mbps	1.2 x 10^{-5}
2	1	0.741	0.141	100 Kbps	1.2 x 10^{-5}
3	2	0.0719	0.121	1 Mbps	1.2 x 10^{-5}
4	3	0.151	0.184	100Kbps	1.2 x 10^{-5}

8. RESULTS AND DISCUSSION

Bit error rate (BER) versus received signal power (PS) plots are shown in Fig. 4 for frequency dependent variance of cyclostationary noise taking numerous values of A_l and B_l (Fourier coefficients). From the plot it is noticed that in a cyclostationary noise environment the BER performance depends significantly on the value Fourier coefficients, A_l and B_l. A set of the optimum values of A_l and B_l of the noise variance that ensures to the best performance.

The values of A_l and B_l are taken from [16], in which the performance analysis is based on simulation method for comparison. The performance results obtained analytically matches well with the simulation results reported in [16]. In Fig. 5, the plots are shown at 100 kb/s data rate. Comparing Fig. 4 and Fig. 5 it can be concluded that at high data-rate a remarkable deterioration in bit error rate (BER) performance occur due to increased noise power at higher bandwidth.

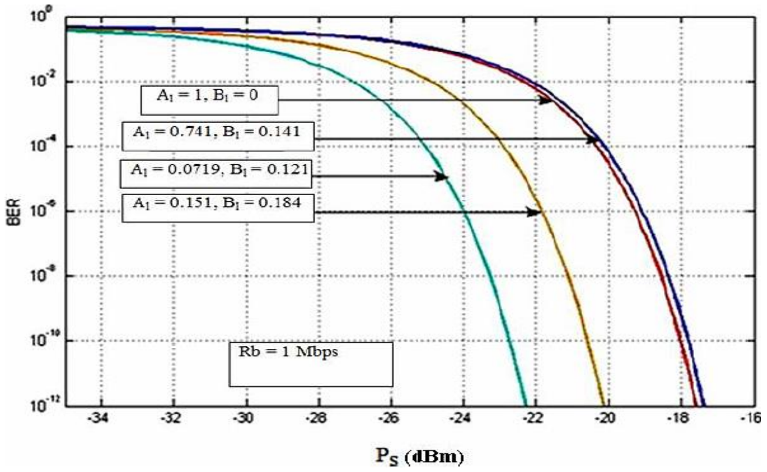

Figure 4. BER versus received signal power P_S (dBm) considering frequency independent cyclostationary noise at a bit rate of 1 Mbps

8.1. Discussion

The BER performance results considering frequency dependence of cyclostationary noise variance $\sigma^2(t)$ are shown in Fig.6 and Fig.7 corresponding to data rate of 1 Mbps and 100 Kbps respectively for set of values of A_l and B_l. It is noticed that receiver sensitivity degrades further due to frequency dependence of the noise variance.

Results for of Receiver Sensitivity vs. Bit Rate, R_b at dependent/independent cases of frequency are depicted in Fig. 8 considering the values of A_l and B_l as above. It can be observed that the PLC channel suffers higher amount of penalty in receiver sensitivity in the frequency-dependent case and the same noise can be regarded as wideband noise.

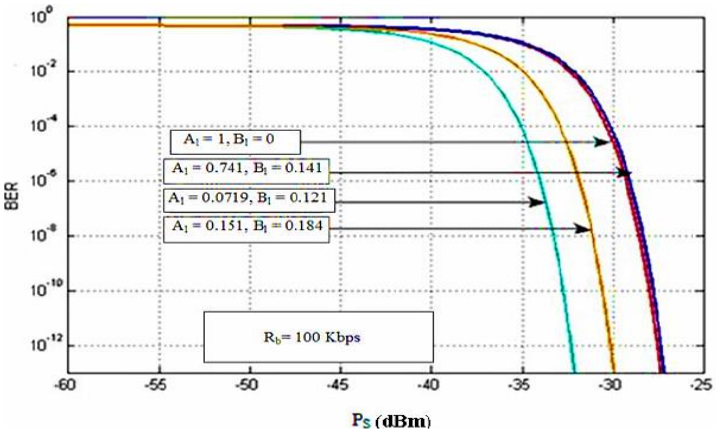

Figure 5. BER versus received signal power P_S (dBm) considering frequency independent cyclostationary noise at a bit rate of 100 Kbps

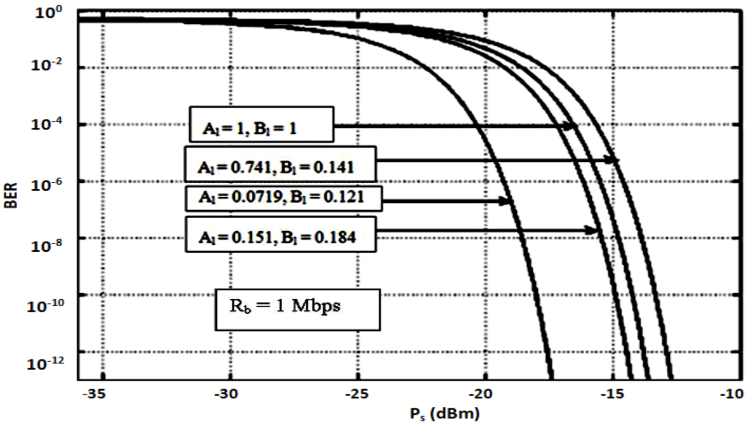

Figure 6. BER versus received signal power P_S (dBm) considering frequency dependent cyclostationary noise at a bit rate of 1 Mbps

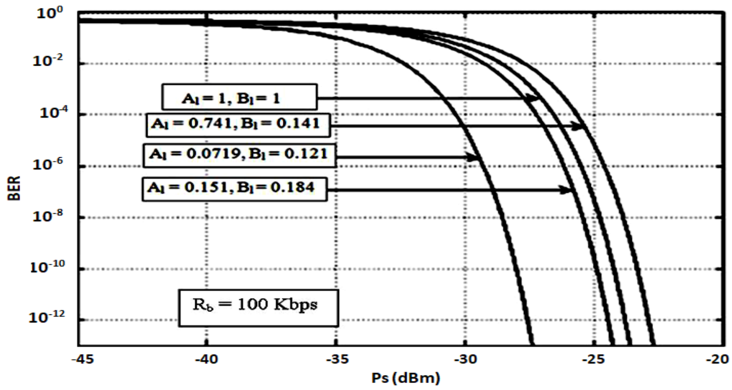

Figure 7. BER versus received signal power P_S (dBm) considering frequency dependent cyclostationary noise at a bit rate of 100 Kbps.

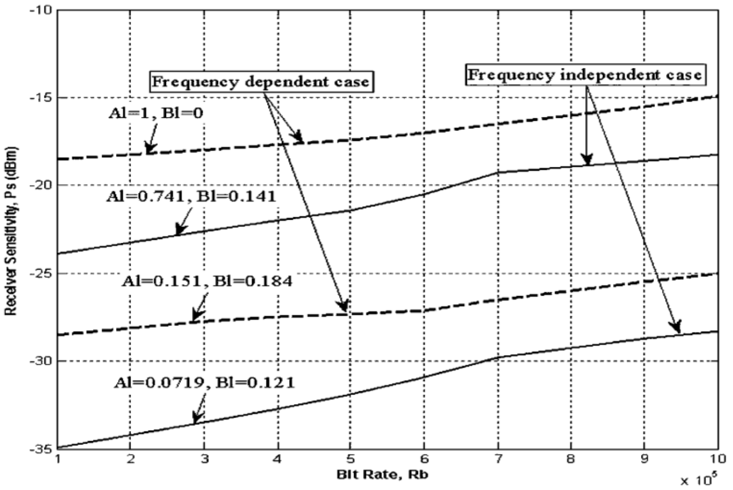

Figure 8. Receiver Sensitivity P_S (dBm) vs. Bit Rate, R_b for both frequency dependent and independent cyclostationary noise for various sets of Fourier coefficients A_l and B_l at a BER of 10^{-6}.

9. CONCLUSSION

In this research work the performance of a powerline communication system in terms of BER is evaluated in the broadband and narrowband frequency. Analytical approach was applied for the system which is severely impaired by non-white cyclostationary noise. A mathematical model with simple probability density function (pdf) which can be expressed with a few numbers of parameters that can describe the powerline hostile noisy channel is proposed in this work. Results are evaluated in terms of bit error rate for frequency dependent bandwidth and also for frequency independent bands, without which PLC noise characterization and analysis cannot be represented using conventional models. This model is found to be an efficient instrument for the evaluation of Power Line Communication (PLC) performance as a whole. Nevertheless, this model not only an important tool for the evaluation noise modeling rather it’s a very powerful tool for the research work of fading and interference in such hostile environment of non-white additive Gaussian noise in PLC channel.

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