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Analysis of Corona Noise in High Voltage Power Line Communication(PLC) under QPSK Modulation in OFDM

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Abstract- ***PLC is a popular communication channel for broadband access, multimedia sharing and as a smart grid. However, there are many disadvantages in PLC and causes deterioration of signal quality, bit error and electromagnetic interferences. High voltage (HV) PLC has been designed ,analyzed and implemented in various modulation protocols such as 4D-TCM,OFDM etc., however study has not been made to investigate its performance in OFDM in QPSK under HV corona noise effects. Corona noise is one of the most influencing noise in high voltage PLC. In HV PLC, corona noise in various weather conditions becomes more dominant and it results a considerable amount of bit error. In this paper , in addition to Additive White Gaussian Noise(AWGN) the effect of corona noise in BER had been investigated. We have used the most popular model of PLC channel- the Zimmermann and Dostert model. The multipath HV lines of 400KV and 220KV installed by Power Grid Corporation of India in the state of Assam has been used for simulation and analysis. Simulation of OFDM with QPSK and the resulting BER under corona noise has been determined.***

Index terms- ***Corona noise, Orthogonal Frequency Division Multiplexing, Power Line Communication,Gaussian Noise,QPSK***

I. Introduction

PLC is an attractive alternative choice for traditional networks due to its ability to offer broadband internet access, cable television, telephone service and home automation. At the same time, the growing demand for multimedia communications provides a good prospect for PLC as a promising transmission technique. In many power transmission companies PLC has been used in SCADA also for remote monitoring of power system informations. However power line communication transmission is affected from many problems such as interference, multipath noise, attenuation delays, presence of echoes, frequency selective fading due to multipath etc [1]. So it is necessary to employ a spectrally efficient multicarrier modulation technique such as orthogonal frequency division multiplexing (OFDM) to counter its unwanted effects on signal transmission. It is found that Low-voltage (LV) and medium voltage (MV) power lines, below 1 kV and from 1 to 36 kV, respectively, are advantageous because they a potentially convenient and inexpensive communication medium for control signaling and data communication. High-voltage (HV) power lines, typically operating at or above 64 kV, can also be used for communication purposes. All communication channels including PLC experiences several types of noises, such as- (i) non stationary colored thermal noise with power spectral density decreasing as the frequency increases, (ii) periodic asynchronous impulse noise related to switching operations of power supplies, (iii) periodic synchronous impulse noise mainly caused by switching actions of rectifier diodes, and (iv) asynchronous impulse noise [5]. On the other hand, performance of the HV power line channel is also limited by disturbances produced by events outside the transmission channel such as, for example, atmospheric phenomena, lightning, or disturbances originating within the system such as network switching, impulse noise, and corona phenomena. Signal transmission in PLC using OFDM techniques has been studied and developed in [2]-[4] to mitigate the common noise effects, however one the most adverse effect of HVPLC- '*corona*' noise has not been addressed for OFDM system. In[5], an optimal 4-D TCM detector has been proposed considering coloured channel noise in HVPLC where corona noise models has been developed based on the work of [6] by digital simulation of corona noise for various HV power lines. An attempt has been made in this paper to study the effect of corona noise in HVPLC and the bit error rate (BER) in OFDM PLC has been determined. The Zimmermann and Dostert model has been used in this paper for simulation. Further as a case study- the multipath HV power lines of 400KV and 220KV installed by Power Grid Corporation of India in the state of Assam has been used for simulation and analysis. Simulation of OFDM with QAM and the resulting BER under corona noise has been determined. The OFDM based receiver structure proposed in [1] (Fig.1) consists of an encoder, a QPSK modulator, Inverse Fast Fourier Transform (IFFT) and Cyclic prefix (CP) insertion respectively in the transmitter side and vice-versa in the receiver side.

The coder adds the redundant information to the sequence of bits. If there is an error in bit chain the redundant information could be used for an error detection and correction by the help of detection and correction coders. The coded bits are then mapped to binary phase shift-keyed (QPSK) symbols. Inverse FFT (IFFT) of the QPSK symbols is taken and a cyclic prefix of length is added to construct the transmitted symbols. The main focus of the algorithm is that-the transmitted signal $s(n)$ passes through the power-line channel $h(n)$, and white Gaussian noise $w(n)$ and corona noise $C(n)$is added, giving rise to the received signal-

$$y(n)=s(n).h(n) + w(n) \quad + C(n) \qquad (1)$$

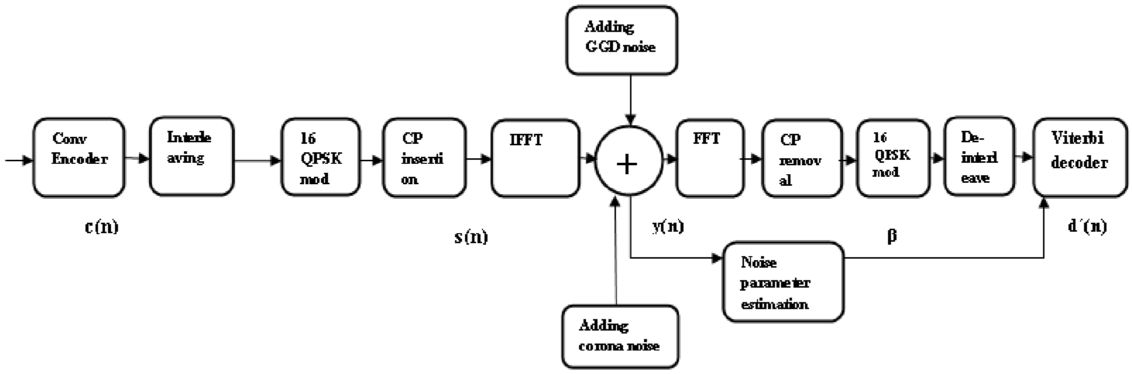


Fig 1. OFDM transmitter-receiver system

II OFDM AND PLC SYSTEM

A. PLC Model

In the past years several approaches for modeling the transfer function of power lines can be found in the literature [7]. The models are represented in a multipath propagation environment. The most widely known model for the PLC channels is the multipath model proposed by Zimmermann and Dostert[8].

The power line is basically a multipath channel caused by reflections generated at the cable branches through the impedance mismatch. The Zimmermann model works in the frequency range from 500 kHz to 20 MHz. This model is based on physical parameters developed from propagation effects and not from properties of the components used in the network, as in the case of other models. A simple 4-path PLC is shown in Fig. 2. The node-A,B,C and D/E are the path-1,path-2,path3 and path-4 topology.

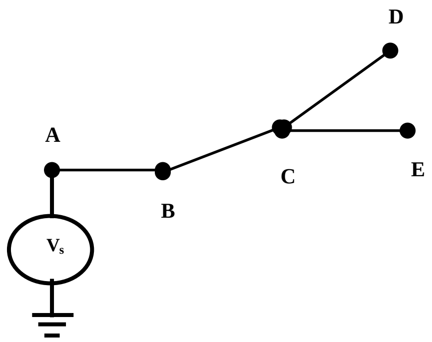


Fig 2. A Multipath PLC topology

Following this model, the frequency response of the channel may be expressed, in the frequency range from 500 kHz to 20MHz, as [1]-

$$H_c(f) = \sum_{i}^{N} \left(g_i \, e^{-(a_0+a_1 f^k)d_t} . e^{-j2\pi f^{\,d_t}/v_p}\right) \qquad (2)$$

where N is the number of relevant propagation paths, a_0 and a_1 are link attenuation parameters, k is an exponent with typical values ranging from 0.5 to 1, g_i is the weighting factor for path *I which is a product of transmission and reflection coefficient of the path*, d_i is the length of the i^{th} path, and v_p is the phase velocity. In this work we consider a PLC channel over the 400KV and 220KV power line grid with parameters [8]shown in Table of section V .

III A CASE STUDY OF HV POWER LINE

The HV power grid line segments of the state of Assam has been implemented in this paper which is taken from the all India power grid map of Power Grid Corporation of India as shown in Fig.3. There are basically two HV grids- 400KV and 220KV and the corresponding substations, their line lengths are shown in Table I and II respectively.

The 400 KV grid within Assam consists of five substations giving rise to two multi path branches considering Kathalguri(KG) as the transmitter-

i) Katahlguri(KG)- Misa(MS) –Bongaigaon(BNG) which forms a 2-path PLC
ii) Katahlguri(KG)-Misa(MS)-Balipara(BLP) Ronganadi(RNG) which forms a 3- path PLC

This multi-path PLC is shown in Fig.5. We have chosen also the 220KV grid considering Barnihat(BNH)(State of Meghalaya) as the transmitter-

i) Bongaigaon(BNG)-Agia(AGI)-Sarusajai(SSJ)-Samaguri(SMG)-Mariani(MRN) which forms a 4-path PLC
ii) Bongaigaon(BNG)--Agia(AGI)--Sarusajai(SSJ)-Samaguri(SMG)—Misa(MS) which forms a 4-path PLC
iii) Bongaigaon(BNG)--Agia(AGI)--Sarusajai(SSJ)-Samaguri(SMG)--Misa(MS)-Dimapur(DMP) which forms a 5-path PLC

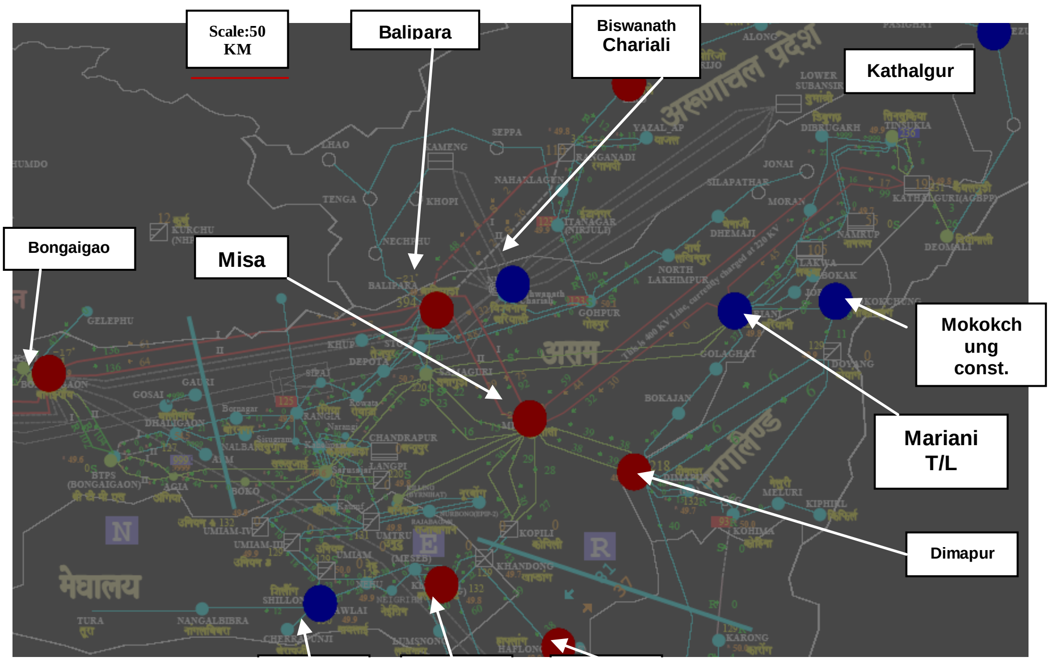


Fig. 3 Map of the HV power grid of Assam
(*Source- Power Grid Corporation of India www.powergridcorporation.com*)

i)

Sa

Misa(MS)-Barnihat(BNH) which forms 5-path PLC

This 220KV multi-path PLC is shown in Fig.4

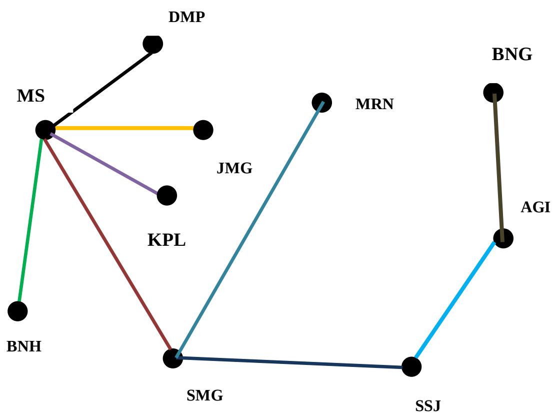


Fig.4 Grid path of 220 KV line

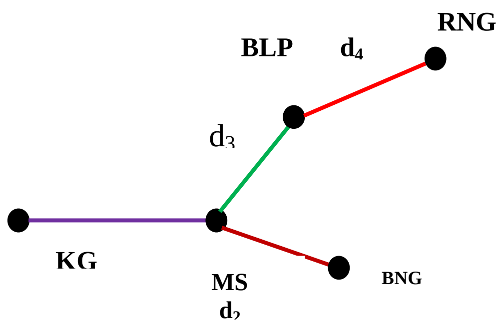


Fig.5 Grid path of 400 KV line

TABLE I
400KV POWER GRID LINE PATHS

Path of Sub station (Code)	Path length (Km)	Branch name
Katahlguri(KG) –Misa(MS)	240	d_1
Misa(MS)-Balipara(BLP)-	80	d_2
Balipara(BLP)-Ronganadi(RNG)-	100	d_3
Misa(MS)-Bongaigaon(BNG)-	20	d_4

TABLE II
220KV POWER GRID LINE PATHS

Path of Sub station (Code)	Path length (Km)	Branch name
Misa(MS)-Jamuguri(JMG)	5	d_1
Misa(MS)-Kopili(KPL)	50	d_2
Misa(MS)-Dimapur(DMP)	60	d_3
Misa(MS)-Barnihat(BNH)	70	d_4
Misa(MS)-Samaguri(SMG)	65	d_5
Samaguri(SMG)-Sarusaji(SSJ)	70	d_6
Samaguri(SMG)-Sarusaji(SSJ)	70	d_6
Sarusaji(SSJ)-Agia(AGI)	80	d_7
Agia(AGI)-Bongaigaon(BNG)	30	d_8
Marian(MRN)-Samaguri(SMG)	160	d_9

IV PROPOSED CORONA NOISE MODEL

Corona in HV power lines is caused by partial discharges on insulators and in air surrounding electrical conductors of power lines .When HV power lines are in operation, the voltage produces a strong electric field around the conductor. This electric field accelerates free electrons present in the air produces collision among the molecules o the air, generating free electrons and positive ion couple. This process continues forming an avalanche phenomenon called 'corona discharge'. There are certain factors on which the corona noise intensity depends such as- the transmission voltage, the size and spacing of the conductors , the type of conductors involved in the line and most importantly the weather conditions [5]. Corona noise models have been developed by many researchers and available in the literature [9]-[11].

A corona noise model has been used in this paper which is considered as a random signal characterized equivalently through its autocorrelation function or its power spectrum.[10]-[11] Hence the corona noise spectrum is generated by a method that takes into account the generation phenomena of corona currents injected in the conductors and the propagation along the line. This spectrum generates an autoregressive (AR) digital filter whose output is described by the expression-

$$n_k = \sum_{i=1}^{N} v_l \, n_{k-1} + w_k \qquad (3)$$

where w_k is a sequence of independent zero-mean Gaussian random variables and v_l is the set of coefficients modeling the corona noise process. The synthesis of the digital filter essentially calls for the identification of the coefficients v_l

proposed in [11]. Considering an order-4 of the corona filter proposed, we have taken the following set of values of v_l for a power transmission voltage of 225 kV [11]-

$$v_1 = -1.225,\ v_2 = 1.052,\ v_3 = -0.603,\ v_4 = 0.217$$

The Gaussian noise (w_k) used in the digital filter of Eqn (3) are taken as -35.4 for fair weather and -17 dB for foul weather for a central frequency of 250 kHz proposed in Table 1 in[9]. In this paper we have simulated the FFT of corona noise generated for both fair and foul weather conditions which are shown in Fig.6 and Fig.7 respectively.

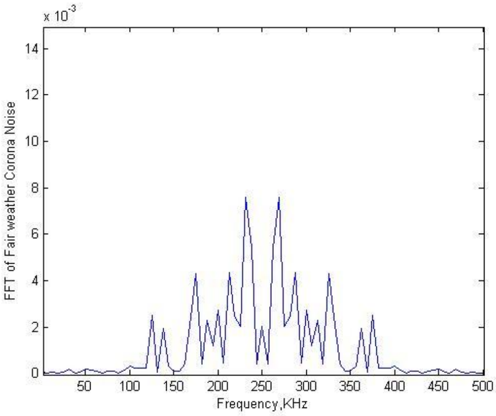


Fig.6 FFT of corona noise (Fair weather)

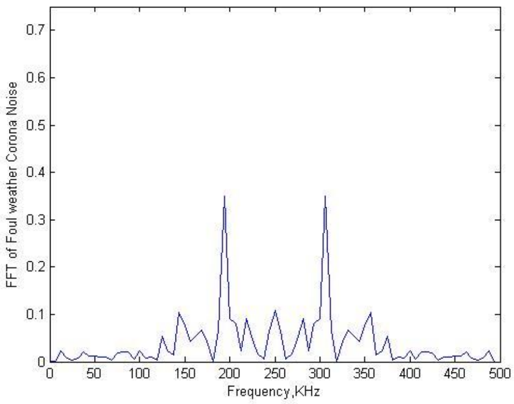


Fig.7 FFT of corona noise (Foul weather)

From Fig. 6 and Fig.7, it is evident that the central frequency of the corona noise is found to be 250KHz . Moreover the corona noise is more severe at foul weather than fair weather which is evident from the amplitude of the FFT.

For simulation of the 400KV PLC channel for OFDM-QPSK transmission and reception we have used model parameters as shown in Table III.[8].Similarly for the 240KV PLC the model parameters are shown in Table IV [8].

Table III
400 KV HV PLC model parameters

K	**Channel parameter**	**Values**
1.0	g_1	1
	g_2	0.38
	g_3	-0.15
	g_4	0.05
	a_0	-2.03×10^{-3}/m
	a_1	3.75×10^{-7}s/m

Table IV
220 KV HV PLC model parameters

K	**Channel parameter**	**Values**
0.7	g_1	0.029
	g_2	0.43
	g_3	0.103
	g_4	-0.058
	g_5	-0.045
	g_6	-0.04
	g_7	0.038
	g_8	-0.038
	g_9	0.071
	a_0	-2.03×10^{-3}/m
	a_1	3.75×10^{-7}s/m

V RESULTS

A. Frequency response of PLC

The frequency response was obtained for the 400KV lines of power grid corporation of India in the state of Assam for a 2-path and 3-path over the range of frequencies for which the model is suitable i.e. upto 200KHz.. The frequency responses were obtained for the channel parameters used for simulation of the PLC channel as shown in Table III. We have considered the actual and physical line length for the four paths as shown in Table I. The 400KV 2-path shows (Fig.8) a single notch at around 20KHz while the 3-path shows multiple notches upto 100KHz. The 400KV PLC mostly exhibit typical attenuation values starting from a few decibels at 20 kHz going up to –70 dB at 100KHz .

Similarly for simulation of attenuation profile of the 220KV PLC, the line lengths are shown in Table II and the line parameters are shown in Table IV. Fig 9 and Fig.10 shows the attenuation profile of the 240KV PLC with- 2nos of each 4-path and 5-path .

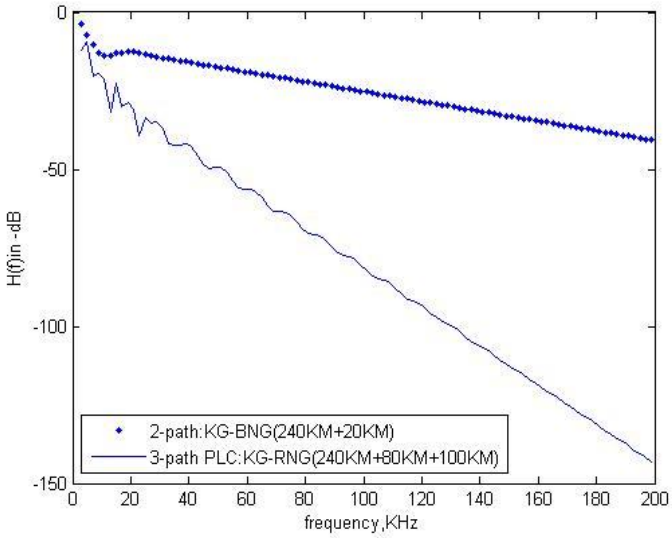


Fig.8 Attenuation profile of Multi-path PLC

In the 4-path attenuation profile, the BNG-MRN path shows a single notch due to $g_9 = 0.071$ while the BNG-MS path does not show any notch due to $g_5 = -0.045$. Same is the case for 220KV 5-path PLC where BNG-DMP path produces a notch due to g_3=0.103 while BNG-BNH do not have any notch due to g_4= - 0.058

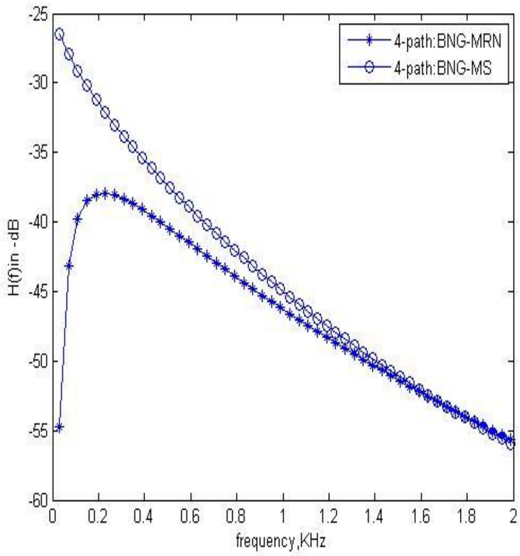


Fig.9 Attenuation profile of 220KV 4-path PLC

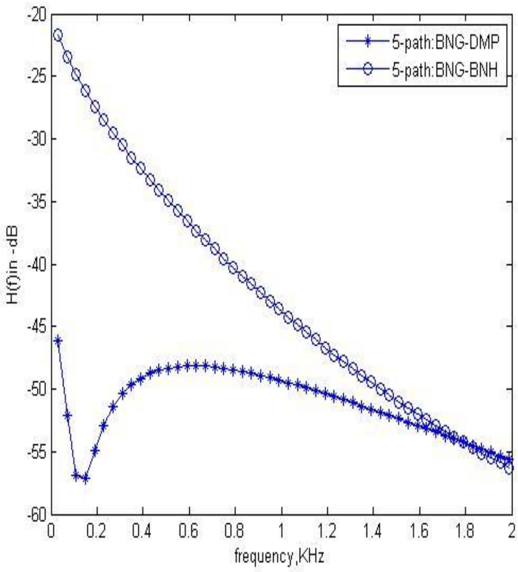


Fig.10 Attenuation profile of 220KV 5-path PLC

B. BER performance analysis in QPSK-OFDM

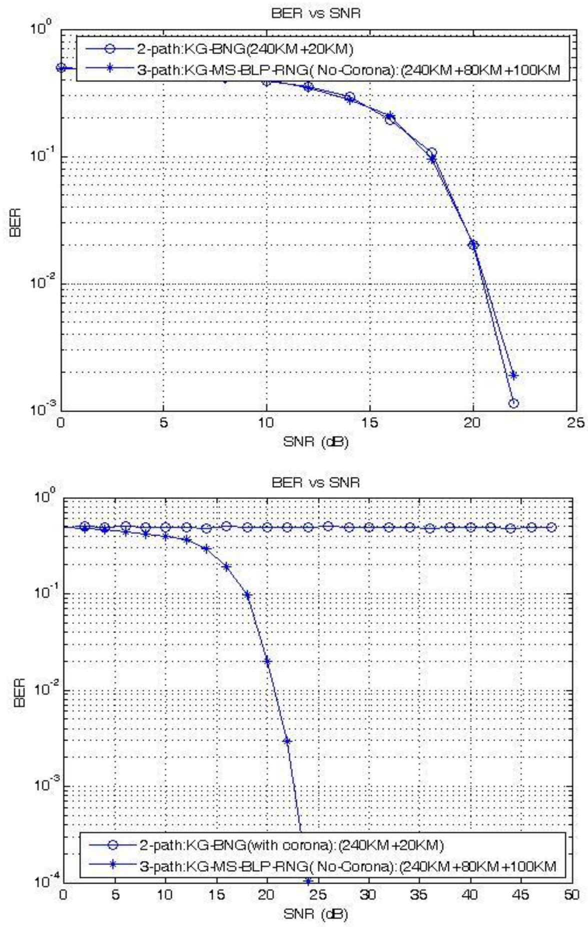
Random data were generated for transmission through the OFDM transmitter and the HV PLC channels explained above in 16-QPSK with the following modulation parameters-

No. of Carriers	: 64
Coding used	: Convolution coding
Single frame size	: 96 bits
Total no. of Frames	: 100
Modulation	: 16-QPSK
No. of Pilots	: 4
Cyclic Extension	: 25%(16)

The corona noise was simulated using equation (3) in HV PLC in digital IR filter domain. Fair weather condition for less severe corona, while severe corona noise in foul weather condition was simulated using different filter coefficients.

The performance of the PLC channel for OFDM under corona noise was studied with the help of BER plot. This is done by obtaining the channel response (in the frequency domain) of the PLC channels with 400KV and 220KV paths as described in Table I-IV .OFDM simulation was carried out with these values by adding AWGN and corona noise.

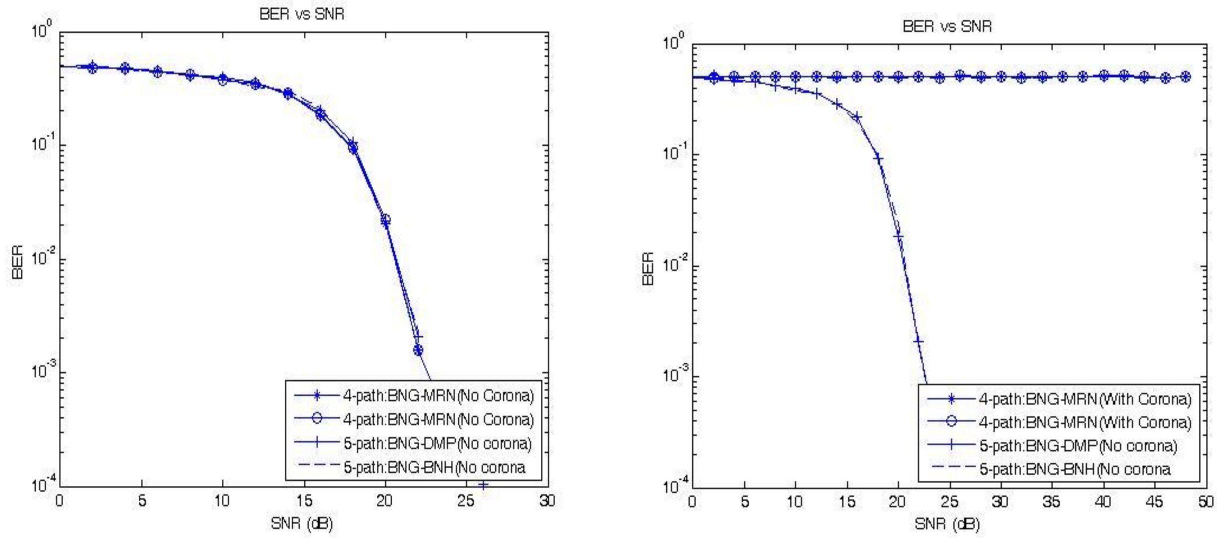
The BER vs SNR plots obtained for the 400KV grid paths are shown in Fig.10



(a) (b)

Fig.10. BER for 400KV (a) 2-path & 3 path-without corona (b) 2-path(without corona) & 3-path(with corona)

The PLC in OFDM was simulated to generate corona noise in KG-RNG path. Fig.10(b) which shows the BER of the corona induced path is quite high for the least SNR condition. The BER vs SNR plots obtained for the 220KV grid paths are shown in Fig.11. Moreover, we have simulated corona noise for two different weather conditions as shown in Fig.11 (b).



(a) (b)

Fig.11 BER for 220KV (a) 4-path & 5-path without corona (b) 4-path with fair weather corona & 5-path without corona

In Fig.11(a) the BER response for 4 pathand 5 path shows the same response when corona noise is not added to anyof the paths. On the other hand the BER in 4-path BNG-DMP branch(Fig.11(b)) with fair weather corona shows much higher BER response than in 5-path BNG-BNH branch without corona.

VI CONCLUSION

In addition to AWGN, corona noise is found to be a major interfering noise in HV PLC in OFDM. This paper shows that the performance of OFDM is affected by corona noise with the variation of the branch lengths in the multipath and different weather conditions. The BER plots prominently shows that the corona noise is a major factor in addition to AWGN. Hence there are potential scope for designing OFDM-receivers with appropriate filters to filter the corona noise which has been published by the authors of this paper in other works.

References

[1] Tayyar Güzel, Eser Ustünel, Hasan Basri Celebi, Hakan Deliç, senior member, IEEE, and kivanç mihçak, member,IEEE,."*Noise Modeling and OFDM Receiver Design in Power-line Communication*". IEEE Transactions on Power Delivery, Vol. 26, no. 4, October 2011.

[2] Sakshi Chawla and Abhijeet Kumar, "*Performance analysis of OFDM under PLC channel*,"International Journal of Research and Innovation in Computer Engineering, Volume 1, issue 2, issn 2249-6580, (46-52).

[3] Opatija Croatia and Mario, Bogdanovi, "*Power line communication system and modeling based on coded OFDM*," MIPRO 2012 , Opatija, Croatia.

[4] P. Mlynek etal ," *OFDM model for power line communication, Latest trends on communications and information technology*", May 21-25,2012,

[5] Riccardo Pighi and Riccardo Raheli,Linear," *Predictive Detection for Power Line Communications impaired by Colored Noise*", Hindawi Publishing Corporation Eurasip Journal on Advances in Signal Processing Volume 2007, Italy

[6] P Burrascano etal, "*Digital Generator of corona Noise on Power line carrier channel*", IEEE Transc. On Power Delivery , Vol 3, No.3, pp 850-854, July, 1988

[7] Ferreira, H.C., Grove, H.M., Hooijen, O. Vinck, A.J.. "*Power line communications: an overview*", Proc. of IEEE ISPLC, 1996, pp. 558- 563

[8] Manfred Zimmermann and Klaus Dostert,"*A multipath model for the powerline channel*," IEEE Transactions on Communications, vol. 50, no. 4, April 2002

[9] N. Suljanoviˊc, A. Mujˇciˊc, M. Zajc, and J. F. Tasiˇc, "*Computation of high-frequency and time characteristics of corona noise on HV power line*," IEEE Transactions on Power Delivery, vol. 20, no. 1, pp. 71–79, 2005

[10] P. Burrascano, S. Cristina, and M. D'Amore, "*Performance evaluation of digital signal transmission channels on coronating power lines*," in Proceedings of IEEE International Symposium on Circuits and Systems (ISCAS '88), vol. 1, pp. 365–368, Espoo, Finland, June 1988

[11] P. Burrascano, S. Cristina, and M.D'Amore, "*Digital generator of corona noise on power line carrier channels*," IEEE Transactions on Power Delivery, vol. 3, no. 3, pp. 850–856, 1988

