International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 13 (2015)

Non Data Aided SNR Estimation for OFDM Signals using Machine Learning Algorithms

K.Seshadri Sastry

Professor
Department of Electronics and Communication, SVECW, Bhimavaram, India
email aditya_shas@yahoo.com

Abstract
This paper deals with the problem of non data aided (NDA) signal to noise ratio (SNR) estimation of OFDM signals transmitted through unknown multipath fading channel. Most of present day's SNR estimators are based on the knowledge of pilot sequences which is not applicable in some contexts such as cognitive radio for example. In this paper we propose a new NDA SNR estimator which uses machine learning algorithms to estimate SNR. The proposed SNR estimation algorithm is compared with existing SNR estimation algorithms, simulation results proved that the proposed algorithm performs better than existing SNR estimation algorithms.

Keywords NDA SNR estimation · Machine Learning · QAM signals

1. Introduction

The SNR (Signal-to-noise ratio) value is defined as the ratio of the desired signal power to the noise power in the communication channel, SNR is an important measure of the channel quality in many modern wireless communication systems. SNR estimation is often required in modern wireless communication systems since the knowledge of the SNR is typically used in adaptive coding and modulation, soft decoding procedures, mobile assisted handoff, and diversity, as well as channel assignment. In literature there are two approaches to determine SNR value in a channel. One is to estimate the ratio of the signal power and the noise variance directly; the other is to obtain the signal power estimate and the noise variance estimate, respectively, prior to SNR estimation.

There are two methods for Signal power estimation. In the first method signal power is computed by the estimated values of channel and the pilot data known as data aided estimation, and in the second approach signal power information is estimated after the noise estimation by the second-order moment of the received signal and this method is known as non data aided estimation.

On the other hand, in determining the noise variance, either we estimate the noise variance by the constructed new noise samples, or we estimate the noise variance by subtracting the estimated signal power from total received power after signal power estimation

Several OFDM SNR estimators have already been suggested [34] and [35] but most of them are based on the pilot symbol knowledge. This kind of estimation method is commonly classified as data-aided (DA). DA algorithms proved their efficiency but cannot be applied in every context. To overcome DA method limitations, a non data aided (NDA) SNR estimator for OFDM systems is introduced in [2]. It can achieve good accuracy but its performance is based on a subjective choice of a threshold level. Moreover, the signal and noise power are not estimated independently which results in performance degradation at high SNR. To overcome the disavantages of [1], K.Seshadri Sastry et al has proposed Non data aided SNR estimation algorithm[2], in [3] non data aided SNR estimation based on periodic redundancy induced by the cyclic prefix is proposed but it assumes a perfect synchronization at reception (i.e. $\tau = 0$ and $\varepsilon = 0$) which resulted in NDA SNR estimator with reduced accuracy. In [4] *Martin VONDR* et al proposed NDA SNR estimation algorithm for speech signals, In [5],[11],[19],[31] and [34] authors proposed various non data aided SNR estimation algorithms. In [1] and [13] non data aided SNR estimation algorithm in the presence of carrier frequency offset for OFDM signals is presented. In [6] Marcos Álvarez-Díaz et al proposed SNR estimation algorithm for Multilevel Constellations using Higher-Order Moments. In [10] Ayesha Ijaz et al proposed non data aided SNR estimation algorithm based on sixth order statistics. In [16] David R. Pauluzzi et al compared various SNR estimation algorithms. This paper is organized as follows, in section 2 the proposed algorithm is explained, in section 3 simulation results of the proposed algorithm are given and section 4 concludes the paper.

2. Proposed Method

The block diagram used to estimate non data aided SNR in the channel proposed method is shown in Fig 2. The input serial data is converted to parallel stream of data using S/P block. The parallel stream of data is modulated by QAM block, IFFT block performs inverse discrete Fourier transformation on the modulated signal. Finally , cyclic prefix is added by the Add CP block before transmitting the signal. At the receiver ML (Machine Learning) block is used to estimate SNR in the channel. Remove CP block removes cyclic prefix in the received signal. FFT block performs discrete Fourier transformation operation on the signal. Demodulation block demodulates the signal and P/S block converts parallel stream of data back to serial data as output.

2.1 ML(Machine Learning) Block

ML block uses Machine Learning algorithms to estimate SNR in the channel. It analyses phase and amplitude information of the received signal and estimates SNR of the signal. The ML block uses Logistic Regression algorithm to predict SNR, constellation diagram of 16 QAM is shown in Fig 1. the length of the phasor gives the amplitude of the carrier signal and the angle of the phasor shows the phase shift of the signal. If there is no noise in the channel (ideal channel) the received signal would have the same amplitude and phase as transmitted signal. If the noise in the channel increases, the received signal is deviated in amplitude or phase, this deviation in amplitude and phase is directly proportional to noise in the channel i.e if noise in the channel increases, deviation of amplitude or phase of received signal from that of carrier signal increases. Further, this deviation of amplitude or phase of received signal from transmitted signal is inversely proportional to SNR in the channel. Since, there is linear relationship between deviation of amplitude or phase of received signal from transmitted signal and SNR, it is a good idea to use logistic regression to predict SNR by observing amount of deviation of amplitude or phase of received signal from transmitted signal. The communication system is simulated in MATLAB and data required to train and cross verify ML algorithm is collected from the simulated system. For the simulated system Additive White Gaussian (AWGN) noise is added in the channel. Data consisting amplitude and phase shift of the received signal is collected at the various values of SNR in the channel. Deviation of amplitude of the received carrier signal at the receiver is shown in figure 3. Deviation of phase shift of the received carrier signal at the receiver is shown in figure 4. Linear regression model to predict SNR in the channel is shown in figure 5.

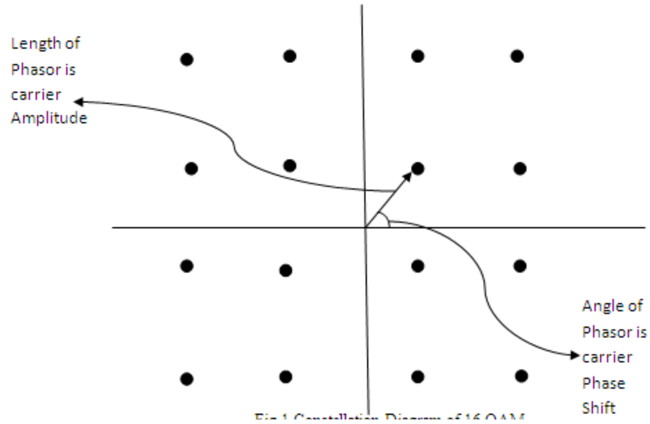

Fig 1 Constellation Diagram of 16 QAM

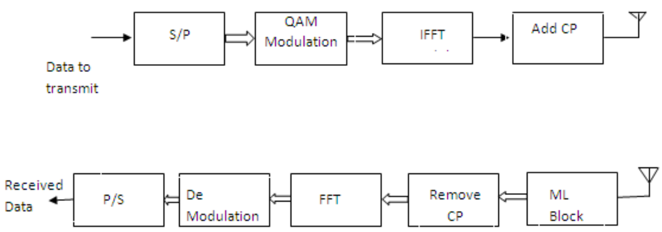

Fig 2 Block Diagram of Communication system using ML Block assisted SNR Estimation

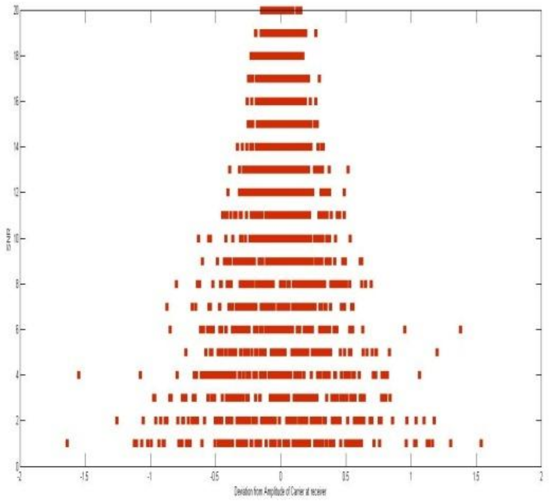

Figure 3 Deviation of Amplitude of Carrier at the receiver

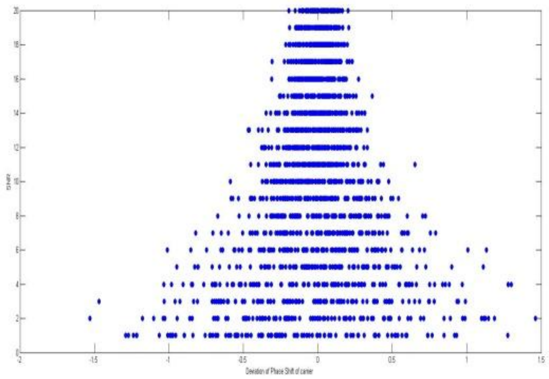

Figure 4 Deviation of Amplitude of Phase Shift at the receiver

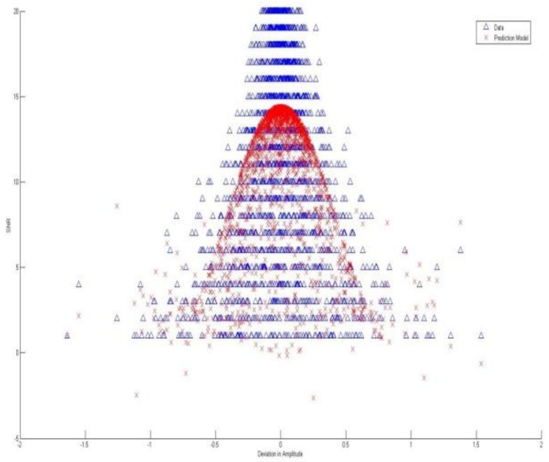

Figure 5 Proposed Model to Predict SNR in Channel

3. Results

To evaluate the performance of proposed estimator computer simulations are carried out. The proposed system is simulated using MATLAB and the block diagram of the system is shown in figure 2. The NMSE is defined as $E|(\text{SNResti}/\text{SNRact})2|$ where SNResti refers to SNR estimated using NDA SNR estimators and SNRact refers to actual SNR. Fig. 6 shows the normalized mean square error (NMSE) of the SNR variance estimation versus SNR. The NMSE shown in figure 6 shows that the estimation error is less for higher values of SNR compared to lower values of SNR.

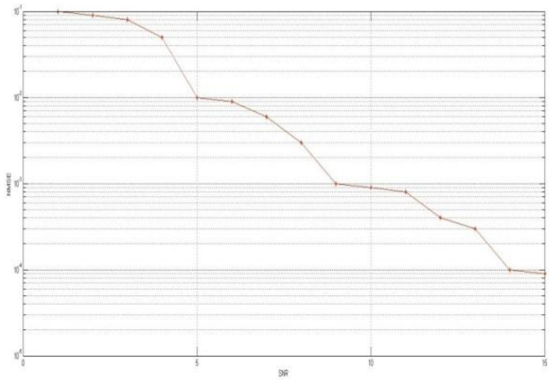

Figure 6 Normalized Mean Square Error (NMSE) of the SNR variance estimation versus SNR

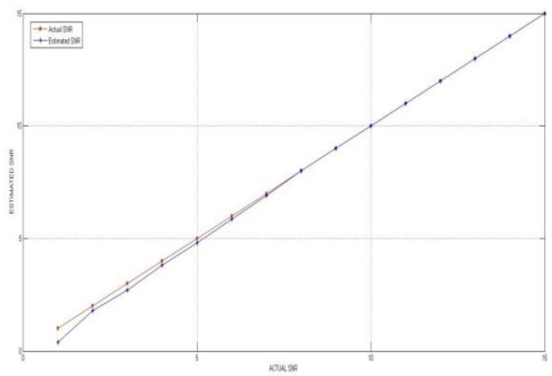

Figure 7 Actual SNR vs Estimated SNR

In Fig. 7 shows the comparison of estimated SNR vs Actual SNR. Simulation results indicate that the proposed NDA SNR estimator exhibits good results, the estimated SNR is very close to actual SNR. Further, accuracy of estimation is better for higher value of SNR compared to lower values of SNR.

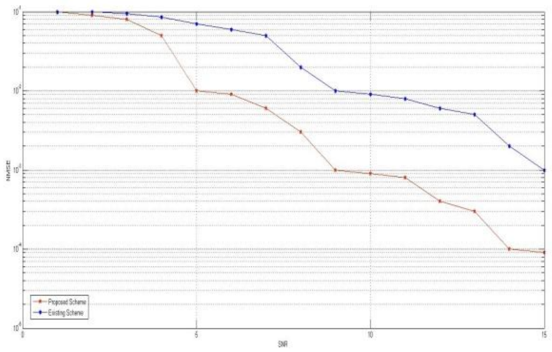

Figure 6 Comparison of NMSE vs SNR for the proposed scheme with existing scheme

Comparison of Normalized Mean Square Error of the SNR variance estimation versus SNR for the proposed scheme and existing scheme[3] is shown in figure 8. Simulation results confirmed that the performance of proposed scheme is better compared to the existing scheme.

4. Conclusion

Non data aided SNR estimation algorithm using Machine learning algorithms is proposed in this paper.

The proposed algorithm exhibited good estimation accuracy compared to the existing SNR estimation algorithms. Further, the estimated SNR using the proposed algorithm is very close to actual SNR in the channel.

References

1. K.Seshadri Sastry, Prasad Babu M.S. (2013), "Non Data Aided SNR Estimation for OFDM Signals in Frequency Selective Fading Channels" Wireless Personal Communications, Volume 70, issue 1, , May 2013,pp 165-175, DOI 10.1007/s11277-012-0686-3, print ISSN 0929-6212, online ISSN 1572-834X, Springer journal.
2. Cui, T., & Tellambura, C. (2006). Power delay profile and noise variance estimation for OFDM. IEEE Communication Letters, 10, 1.
3. Socheleau, F.-X., Aïssa-El-Bey, A., & Houcke, S. (2008). Non data-aided SNR estimation of OFDM signals. IEEE Communication Letters, 12, 11.
4. Martin VONDR´ASˇE and Petr POLLA´K, Methods for Speech SNR estimation: Evaluation Tool and Analysis of VAD Dependency, RADIOENGINEERING, VOL. 14, NO. 1, APRIL 2005
5. Ami Wiesel, Jason Goldberg, and Hagit Messer," Non-Data-Aided Signal-to-Noise-Ratio Estimation",
6. Marcos Álvarez-Díaz, Roberto López-Valcarce and Carlos Mosquera," SNR Estimation for Multilevel Constellations Using Higher-Order Moments", IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 58, NO. 3, MARCH 2010
7. K.Seshadri Sastry, Prasad Babu.M.S(2013), "Adaptive Population Sizing Genetic Algorithm Assisted Maximum Likelihood Detection of OFDM

Symbols in the Presence of Nonlinear Distortions" International Journal of Computer Network and Information Security, June 2013, Volume 5, issue 7, pp 58-65, DOI: 10.5815/ijcnis.2013.07.07, , print ISSN 2074-9090, online ISSN 2074-9104, MECS publications, Hong Kong.

8. K.Seshadri Sastry," Adaptive Modulation Using Neuro-Fuzzy (N-F) Controller for OFDM System", Vol. 1, No. 2, pp. 85-89, June 2013. DOI: 10.12720/ijeee.1.2.85-89, 2013 4th International Conference on Signal and Information Processing, 06-07 July 2013, Kowloon, Hong Kong.
9. Prasad Babu .M.S, K. Seshadri Sastry , "Secant Method Based ML Estimation of Carrier Frequency Offset in OFDM System", International Journal of Computer Science and information Security, ISSN 1947-5500, April 2012, Volume 10(4), pp 125-128.
10. Ayesha Ijaz, Adegbenga B. Awoseyila and Barry G. Evans," IMPROVED SNR ESTIMATION FOR BPSK AND QPSK SIGNALS
11. R. López-Valcarce and C. Mosquera, "Sixth-order statistics based non data-aided SNR estimation," IEEE Commun. Letters. vol. 11, no. 4, pp. 351–353, Apr. 2007..
12. K.Seshadri Sastry (2012), "Frequency Offset Estimation Based on Cyclostationary Statistics Induced by Cyclic Prefix" International Journal of Electronics, Computer and Communications Technologies" , May 2012, Vol. 2(3), pp 6-8.
13. Lee, J., Lou, H.-L., Toumpakaris, I., & Cioffi, J. M. (2006). SNR analysis of OFDM systems in the presence of carrier frequency offset for fading channels. IEEE Communication Letters, 5, 12.
14. Jallon, P. (2008). An algorithm for detection of DVB-T signals based on their second order statistics. EURASIP Journal on Wireless Communications and Networking, 2008(article ID 538236).
15. K.Seshadri Sastry, Prasad Babu .M.S (2010), "Code Division Multiplexing Using AI Based Custom Constellation Scheme – Efficient Modulation for High Data Rate Transmission" International Journal of Engineering Science and Technology (ISO Certified), ISSN: 0975-5462, June 2010, Volume 2 (6) , pp 2377-2383 .
16. David R. Pauluzzi and Norman C. Beaulieu, "Comparison of Four SNR Estimators for QPSK Modulations," IEEE Communication Letters, vol. 4, no. 2, pp. 43.45, Feb. 2000.
17. M. K. Simon and A. Mileant, "SNR estimation for the baseband assembly," Jet Propulsion Lab., Pasadena, CA, Telecommunications and Data Acquisition Prog. Rep. 42-85, May 15, 1986.
18. K.Seshadri Sastry, Prasad Babu .M.S (2010), "Fuzzy Logic Based Adaptive Modulation Using Non Data Aided SNR Estimation for OFDM System" International Journal of Engineering Science and Technology (ISO Certified), ISSN: 0975-5462, June 2010, Volume 2 (6), pp 2384-2392.
19. Wiesel, J. Goldberg, and H. Messer, "Non-data-aided signal-to noise- ratio estimation," in Proc. IEEE Int. Conf. Commun., Apr. 2002, vol. 1, pp. 197–201.
20. S. M. Kay, Fundamentals of Statistical Signal Processing—Detection Theory. Englewood Cliffs, NJ: Prentice-Hall, 1998.
21. N. L. Johnson and S. Kotz, Distributions in Statistics—Continuous Univariate Distributions—2. Boston, MA: Houghton Mifflin, 1970.
22. K.Seshadri Sastry, Prasad Babu .M.S (2010), "AI Based Digital Companding Scheme for OFDM System Using Custom Constellation Mapping and Selection" International Journal on Computer Science and Engineering, ISSN: 0975-3397, July 2010, Volume 2 (4), pp1381-1386.
23. Pollet, T., Bladel, M. V., & Moeneclaey, M. (1995). BER sensitivity of OFDM systems to carrier frequency offset and wiener phase noise. IEEE Transactions on Communications, 43(2/3/4), 191–193.
24. Daffara, F., & Chouly, A. (1993). Maximum likelihood frequency detectors for orthogonal and multicarrier systems. In Proceedings of 1993 IEEE international conference on communications (pp. 766–771).
25. Lashkarian, N., & Kiaei, S. (2000). Class of cycle-based estimator for frequency offset estimation of OFDM systems. IEEE Transactions on Communications, 48(12), 2139–2149.
26. K.Seshadri Sastry, Prasad Babu .M.S (2010), "Custom Modulation Scheme for Enhanced Voice Quality in Software Defined Radio ", IEEE ICSESS 2010, Beijing , China, pp 376-379.
27. E. Nemer, R. Goubran and S. Mahmoud, "SNR Estimation of speech signals using subbands and fourth-Order statistics,"IEEE Signal Processing Letters, vol. 6, no. 7, pp. 171-174, Fig. 4 shows the average of the estimated SNRs obtained July 1999.
28. K.Seshadri Sastry, Prasad Babu .M.S (2010), "Adaptive Modulation for OFDM System Using Fuzzy Logic Interface", July 18, 2010, IEEE ICSESS, PP 368-371.
29. Wang, X. & Poor, H. W. Wireless Communication Systems, ISBN: 0137020805.
30. Tong, L., & Perreau, S. (1998). Multichannel blind channel estimation: From subspace to maximum likelihood methods. IEEE Proceedings, 1998, 1951–1968.
31. K.Seshadri Sastry, Prasad Babu .M.S (2010), " SNR Estimation for QAM Signals Using Fuzzy Logic Interface", IEEE ICCSIT 2010, July 2010, pp 413-416
32. K. Balachandran, S. Kabada, and S. Nanda, "Rate adaptation over mobile radio channels using channel quality information," in Proceedings of IEEE Global Telecommunications Conference, Globecom'98 Communication Theory Mini Conference Record, 1998, pp. 354-356.
33. K.Seshadri Sastry, Prasad Babu .M.S (2010)," AI Based Digital Companding Scheme for Software Defined Radio" IEEE ICSESS , 2010, pp 417- 419
34. K. Balachandran, S. R. Kadaba, and S. Nanda,

"Channel quality estimation and rate adaption for cellular mobile radio," IEEE J. Sel. Areas Commun., vol. 17, no. 7, pp. 1244–1256, Jul. 1999.

35. K.Seshadri Sastry, Prasad Babu .M.S (2010) ,"Digital Companding Scheme Using AI Based Custom Constellation Mapping and Selection", IEEE ICSESS 2010 , Beijing , China, pp 364-367.

36. Xu, H., Wei, G., & Zhu, J. (2005). A novel SNR estimation algorithm for OFDM. In Proceedings of IEEE vehicular technology conference (Vol. 5, pp. 3068–3071).

37. Yi, W., Lihua, L., Ping, Z., Zemin, L., & Yu, Z. (2007). A new noise variance estimation algorithm for multiuser OFDM systems. In Proceedings of IEEE conference on personal, indoor and mobile radio communications (pp. 1–4)

38. K.Seshadri Sastry (2012) "Adaptive Modulation for OFDM System Using Fuzzy Logic Interface" in book named "Digital Communications", published by Intech publications, Croatia, Europe, March 2012, pp 119-138.