Journal of Engineering and Applied Sciences 14 (Special Issue 6): 9358-9370, 2019
ISSN: 1816-949X

Design of LTE System by using Neural Network Adaptive Equalizer Based on Discrete Fourier and Wavelet Transforms

Alaa Shakir, Osama Qasim Jumah Al-Thahab and Laith Ali Abdul-Rahaim
Depatment of Electrical, College of Engineering, University of Babylon, Hillah, Iraq

Abstract: The performance of Discrete Wavelet and Fast Fourier Transform (DWT and FFT) is examined in Orthogonal Frequency-Division Multiplexing (OFDM) that uses in the Long-Term Evolution (LTE) system. The DWT has some advantages compared to FFT which enables the operation of a time frequency range that allows accuracy and optimal flexibility. Wavelet has been implemented satisfactorily in the all areas of systems that depend on wireless communication of LTE utilization. In this resaerch, the performance of the LTE system was improved using multiple antenna technology via. the Riley channel. LTE-Based wavelets outperform LTE-based FFT in all scenarios. The Bit Error Rate (BER) is an important thing with the Signal to Noise Ratio (SNR) is founded for the proposed and general system and then a suitable comparison is made between them when using the feed forward neural network equalizer instead of the traditional one. The proposed structure aim to improve the LTE system performance under different channel conditions, so that, a high data rate and a low BER are satisfied. All LTE system Models are employed in MATLAB 2017b to have the ability of varying the system parameters like channel types, channel's parameters, SNR and BER.

Key words: LTE, discrete wavelet transform, channel estimation, feed forward neural network equalization, FFT, flexibility

INTRODUCTION

In recent years, there are many researches that are developing LTE physical layer by many scientists and engineers in order to meet the requirements of 4G system specifications such as audio stream as multimedia applications in addition to interactive games, mobile TV, the internet and video browsing. For that purpose a new approaches is needed for applications of multimedia and this increase in the use of mobile data LTE technologies. 3 GPP identified as emerging technologies for the next generation of telecommunications networks of mobile and WLAN. The designers of all wireless system aims to obtain a high data rate to fixed nodes with minimum BER and different mobile users under multi-channel models. To reduce the elements of the network, the capacity of the system should be improve beside the capacity of the coverage area in addition to high rates of data for high performance and low latency access operation through a suitable bandwidth (Linfoot *et al*., 2007).

A global framework provided by LTE for 4G systems enables high speed and low delay data with messages may be unified or multimedia. The 3GPP LTE version 10 improves LTE-A system specified existing LTE systems to give higher data rate with much possible usage, latency low beside thes pectral efficiency is better. Kumbasar Volkan and Oguz Kucur refers in their study, the use of wavelet conversion in LTE systems with derived mathematical expressions to represent the data rate in LTE transmission based on wavelet and Fourier transformations. They obtain good results for a small group of multiple carriers. The performance is taking via. multi-path Riley channels with a power delay profile (Shadmand *et al*., 2011). Mobil applications supported by LTE technology forming in their performance a very high and a wide range rate of data proportionate to usage models and density of user (Kumbasar and Kucur, 2012; Yan and Liu, 2004).

Yan and Liu (2004) proposed a new method of OFDM design based on the multiple wavelet package. The design has far fewer flexible side lobes, flexible data rate, more tape efficiency and low to peak power ratio while Daoud (2012), provides a way to improve the MIMO of the OFDM system by suggesting a new method of addressing the PAPR. This reference only adds the use of MIMO technology in the OFDM waveform. The proposed new structures improve the performance of BER in many channel models.

A new approach system of OFDM based on Discrete Multiwavelet Transform (DMWT) and Critical-Sampling Transform (CST) as a turbo codes effectiveness and how useful of providing good BER performance at higher data is discussed by Dawood *et al*. (2015) with their teams Kattoush *et al*. (2013), Anusuya *et al*. (2013) proposes DMWT based orthogonal modulator. By DMWT implementing, a good spectral efficiency and BER can be achieved compare to FFT and DWT. To reach good efficiency of spectral and interference reduction via. multi wavelet, a technology of MIMO is introduced to reduce the effect of channel and increase the data rate performance (Lavanya and Madheswaran, 2014).

Corresponding Author: Osama Qasim Jumah Al-Thahab, Depatment of Electrical, College of Engineering, University of Babylon, Hillah, Iraq

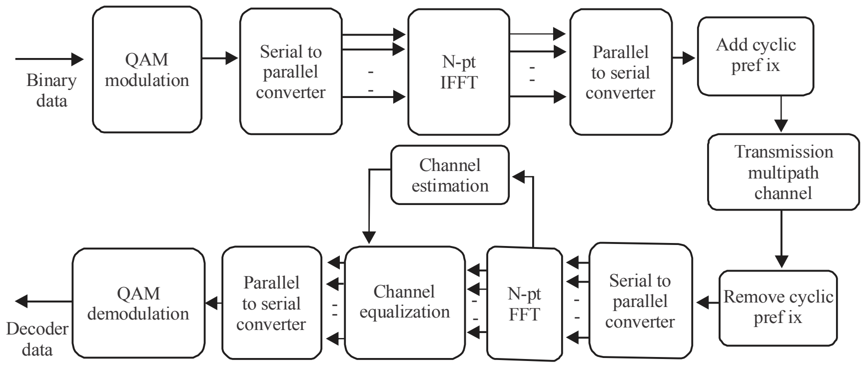

Fig. 1: OFDM block diagram

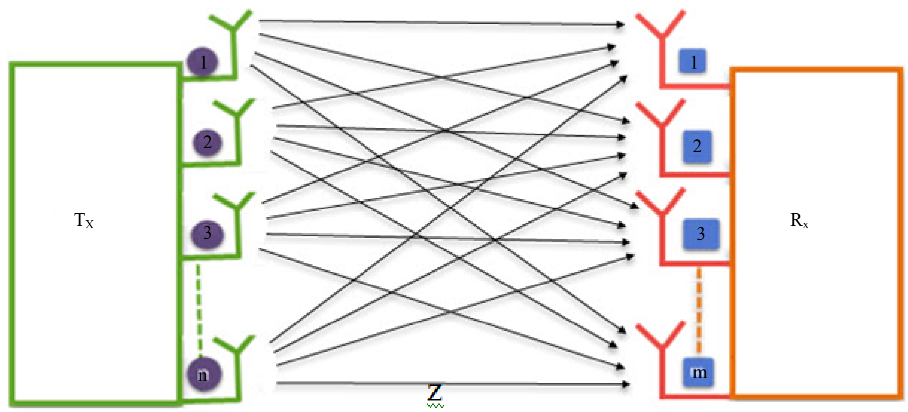

Fig. 2: MIMO structure

MATERIALS AND METHODS

LTE structure: Generally, LTE transmitters and receivers depending on OFDM transvers system which can be shown in in Fig. 1. LTE system can be applied by using FFT and can be simulated via. different channel models like AWGN, flat fading channel and selective fading channel. For transmitting signals, OFDM remains a common technique over wireless channels because of its several compensations such as strong lightness in selective fading, high spectral efficiency in addition to the perform low cost transceivers ability. The key role here is the overcoming of the distortions in channel by estimating channel properties and producean indication about it such as the delay of propagation and the effect of multipath. The estimation techniques are analyzed to enhance the OFDM performance and consequently the LTE system (Ma *et al*., 2012; Sanjana and Suma, 2014).

For multi-carrier transmission, OFDM is a special case, so that, there is one stream of data should be transmit through a number of low-frequency sub carriers. Here, the total datais divided into a number of orthogonal sub-carriers. Many telecommunication standards are based on OFDM like Wireless Local Area Network (WLAN), Digital Television Terrestrial (DTT) and digital broadcasting systems, etc. (Bhardwaj *et al*., 2012).

The scheme of Multi-Carrier Modulation (MCM) is OFDM that converts a selective broadband frequency channel to narrow-band parallel channels fading. Cyclic Prefix (CP) is added to dilute the Inter Symbol Interference (ISI) which in turn leads to inefficiency of spectral and it leads to a wave in a Power Spectral Density (PSD) which decreases the transmit power (Batra *et al*., 2004; Bingham, 1990). On the other hand, the use of DWT can adjusted the orthogonality criteria by wavelet filter banks, so, all benefits of the multicarrier system can be obtained which means the utilization of DWT may enhance the immunity to noise and interference capacity can also be greatly reduced (Lindsey, 1995; Negash and Nikookar, 2000; Bouwel *et al*., 2000).

For this reason, OFDM-based wavelets do not require CP which in turn increases the spectral efficiency and ripples with complexity reduction, resulting inhigh code rate and no redundancy waste of energy. In addition, the formation of wavelet bundles will have significantly lower side-lobe signals which reduces the Inter Carrier Interference (ICI). The signal is generated by modifying the input data by using Quadrature Amplitude Modulation (QAM). It is used here, since, it is very effective in saving the bandwidth (Ohno *et al*., 2004; Sakakibara *et al*., 2005).

Figure 2 displays the receiver with transmitter portion respectively with the MIMO idea. Here, the number of

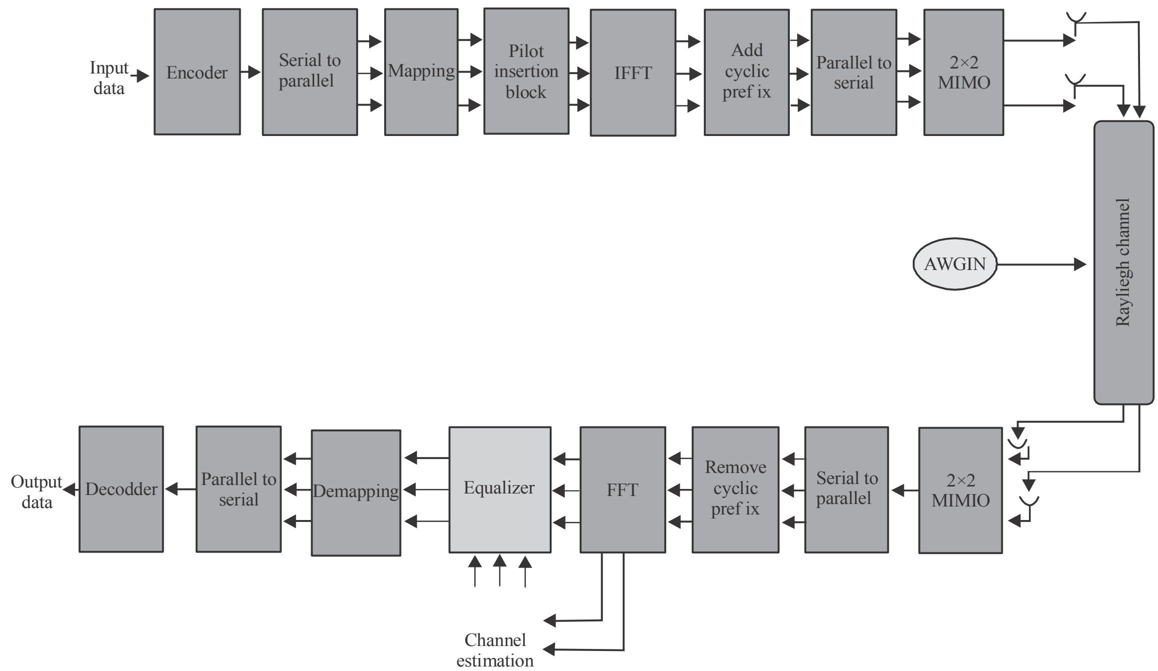

Fig. 3: LTE structure

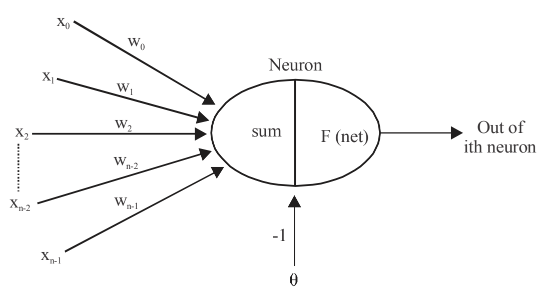

Fig. 4: The neuron model

transmitter is N and the system is considered to be in a multi-user environment of overlapping K users where the user adorned by from antennas, connects to the base station with N antenna (Cho *et al*., 2010). The blockdiagram of LTE system canbe shown with its details in Fig. 3 (Shadmand *et al*., 2011).

Theoretical background of Neural Network (NN): The NN is stimulated from neural human system and used in different areas like optimization, control, pattern recognition, etc. NN stands from several processing units and guide the links between them. The connections that represent the ratio between input and output neurons are the weights and can be shown in Fig. 4 while the output equationsare seen in Eq. 1, 2 (Haddadi *et al*., 2010):

$$\text{Net} = \text{sum} = \sum_{i=0}^{n-1} W_i X_i - \theta \quad (1)$$

$$\text{Output} = f(\text{net}) \quad (2)$$

Where:

W : The Weight of the inputs (x) and is the bias of the neuron

f(net) : The activation function which can be hard limiter, linear or sigmoid activation function

NN imitates afunction and a structure of human brain, so, it considers anon-linear information processing system. It has self-reliance, self-learning ability, very strong nonlinear mapping and self-organizing (Al-Thahab, 2016). NN are categorized into two collections according to connections: Feed Forward Neural Network (FFNN), whichrepresents the function of the current input. Thus, it has no internal condition which means the weights are stay constant, you can see FFNN in Fig. 5. Feed Back Neural Network (FBNN) is another type of NN which formed from the FFNN that seen in Fig. 5 but linking the neuron outputs to their inputs (Chaturvedi *et al*., 2014).

Channel estimation: The sender modifies the sequence of message bits to PSK/QAM codes (this is in OFDM

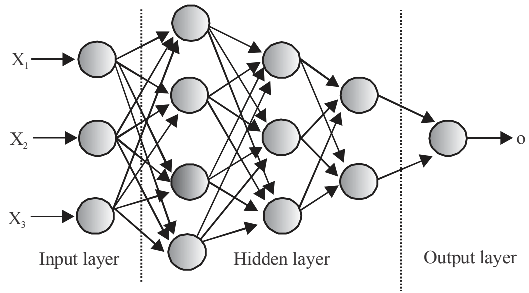

Fig. 5: FFNN discripsion

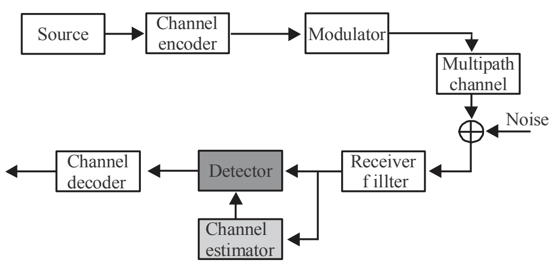

Fig. 6: The block diagram of the channel estimator

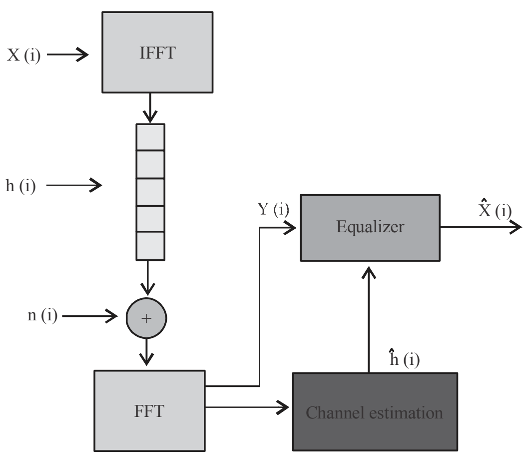

Fig. 7: Equalization method

system). IFFT implements symbols to convert them to time-domain signals and sends them out via. wireless channel. The received signal is usually distorted by channel characteristics. To restore the transmitted bits, the channel effect must be estimated and then compensated. The channel can be estimated by using the boot codes which may known as experimental codes for both transmitter and receiver. These codes use different interpolation techniques to estimate the channel response of the sub-carriers between experimental tones. In general, the data signal as well as the training signal or both can be used to estimate the channel specifications. In order to select the channel estimation technique under consideration, many different aspects of application, required performance, computational complexity and channel time change must be considered (Sanjana and Suma, 2014).

Channel estimation is based on the training sequence of bits which is unique for the transmitter and repeated in every transmitted burst. The channel estimator gives the knowledge on the Channel Impulse Response (CIR) to the detector and it estimates separately the CIR for each burst by exploiting transmitted bits and corresponding received bits. The modulated corrupted signal from the channel has to be undergoing the channel estimation by using LMS, MLSE, MMSE or RMS before the demodulation takes place at the receiver side. The channel estimator is shown in Fig. 6 and the traditional way for estimation is stated in Eq. 3 (Alli, 2012):

Channel equalization: The function of the equalizer is to provide an equivalent transfer function for the transmission function of the channel. The channel corrupts the signal and adds noise to the input signal inside the channel. The signal undergoes from damage and then passed via. a link which may tends to reduce that noise. The output of the link is required to be a late version of the income signal. If the CIR is represented by h (k), the input signal is represented by x (k), the output signal is represented by y (k), the order of the equivalent is N, then instant, y (k) express the required output of d (k) and error e (k) as follows:

$$d(k) = x(n+k-m) \tag{3}$$

$$e(k) = d(k)-y(k) \tag{4}$$

Where:

n (k) : A factor that added a noise in the channel
m : The delay given to the input signal
e (k) : Represents the instantaneous error signal and will always be positive

Weights can vary and adapt together to reduce error. The idea of equalization is shown in Fig. 7 (Sanjana and Suma, 2014; Shahriar *et al*., 2016). X(i) = Y(i)/h'(i), since, h'(i) represents the channel estimation of the transmitted pilots (channel response).

Proposed new LTE system: Here, the proposed system is achieved by three ways: the first way used Inverse Fast Fourier Transform (IFFT) with Feed Forward Neural

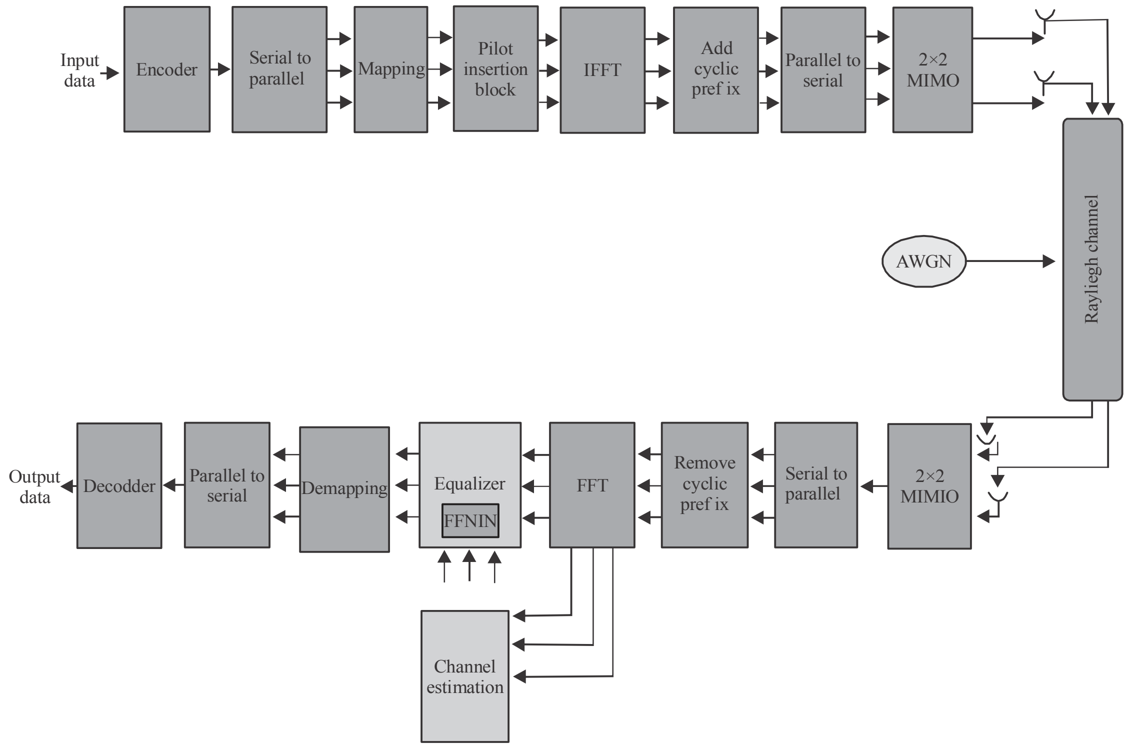

Fig. 8: System blocks with IFFT-FFNN

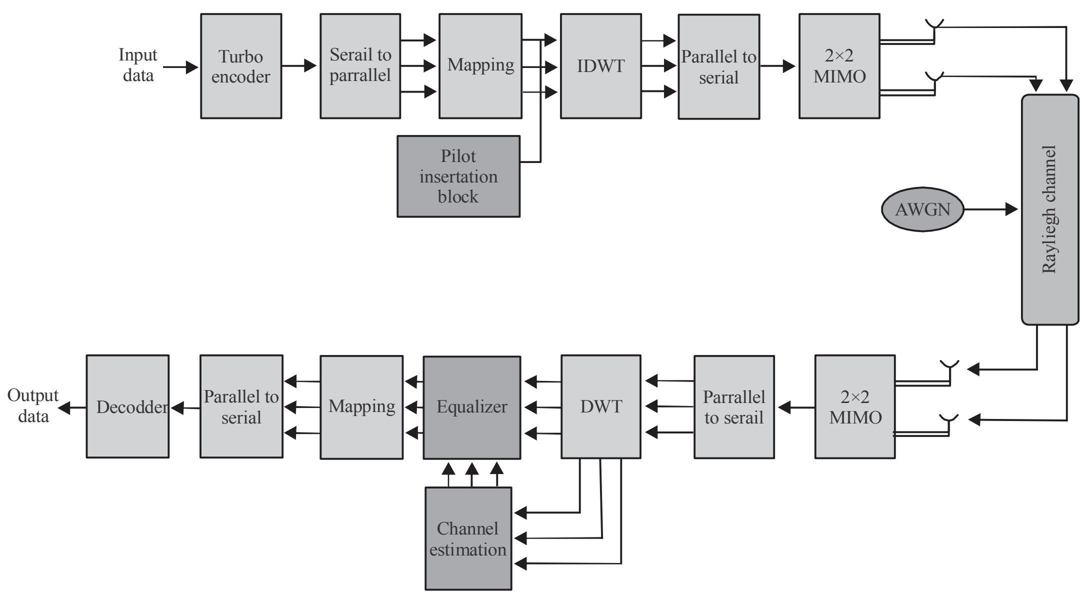

Fig. 9: System blocks with IDWT

Network (FFNN) as seen in Fig. 8. The second way used Inverse Discreet Wavelet Transform (IDWT) instead of IFFT in OFDM as depicted in Fig. 9 while the third way used Inverse Discreet Wavelet Transform (IDWT) with Feed Forward Neural Network (FFNN) as adaptive equalizer as showing in Fig. 10.

It can be seen from Fig. 8 and 9 that when the DWT is used instead of FFT, the CP is removed, since, DWT has better orthogonality than FFT which consequently consider as an advantage to the proposed system. The general block diagram for the proposed system can be shown in Fig. 11.

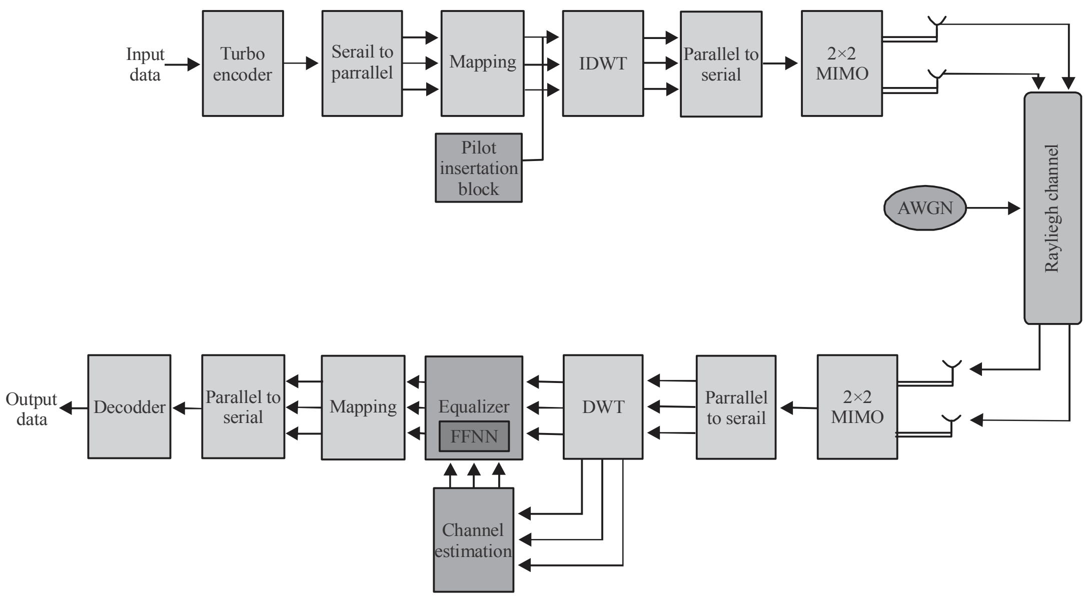

Fig. 10: System blocks with IDWT-FFNN

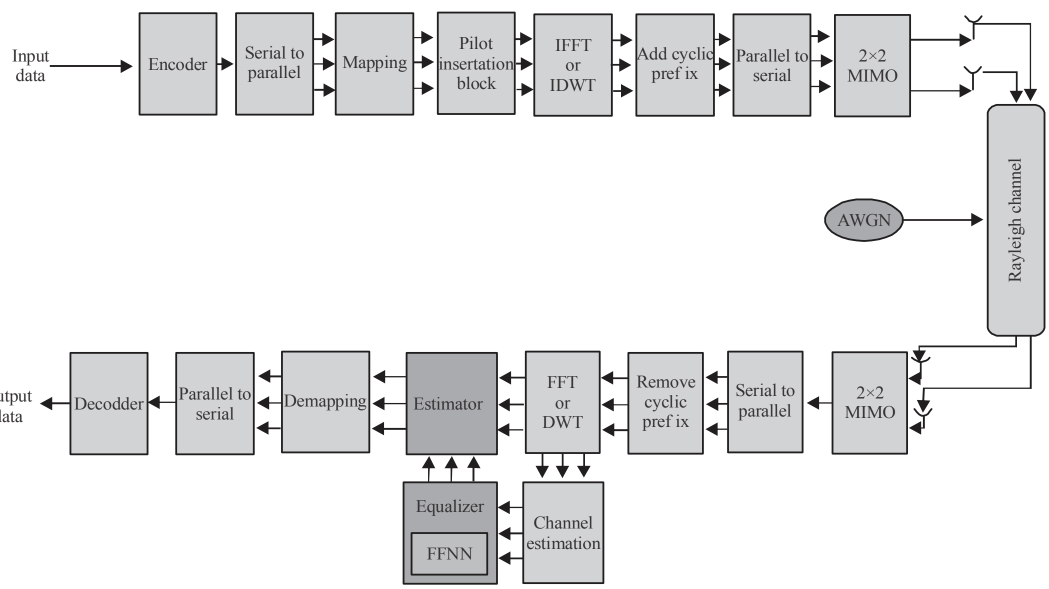

Fig. 11: LTE proposed system general block diagram

RESULTS AND DISCUSSION

Results of simulation of the proposed LTE systems: In this section, the proposed LTE systems are simulated with FFT and DWT by using MATLAB 2017b. The BER performance of the proposed LTE system considered in selective channel and specific LTE channel models with or without frontal neural network feeding. The Doppler Frequency (DF), here is taking within three values: 5 Hz which represents a transmission speed of 2 km h^{-1}, 50 Hz that corresponds to a speed of 20 km h^{-1} and 200 Hz which represent an 80 km h^{-1} speed.

LTE performance in selective fading channel: The LTE itself will be taught by a selective channel model in addition to AWGN. Thus, the transmitted signals will suffer from continuous attenuation and longitudinal distortion via. the MIMO LTE channel Model. The model

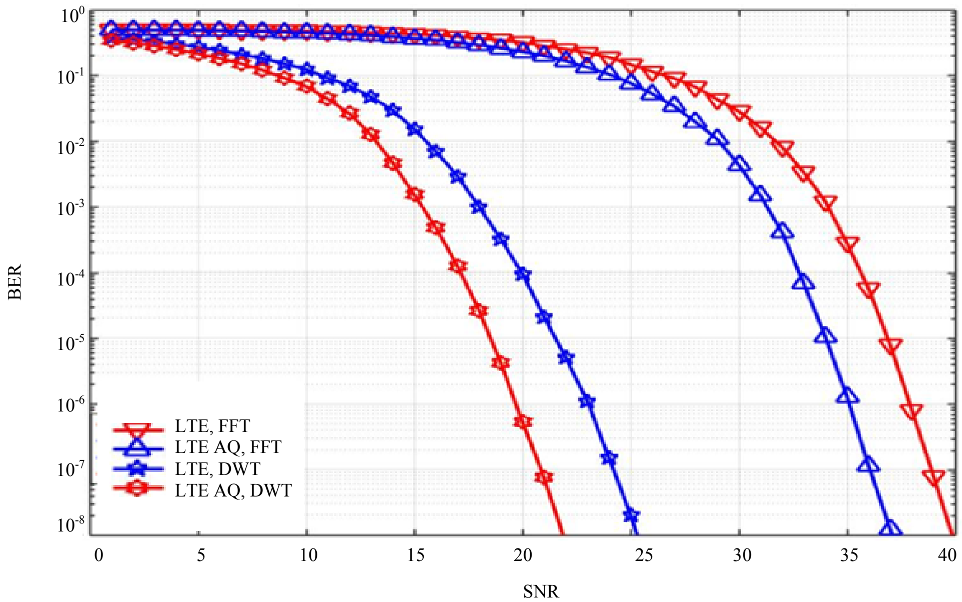

Fig. 12: LTE performance in selective fading channel-MDS = 5

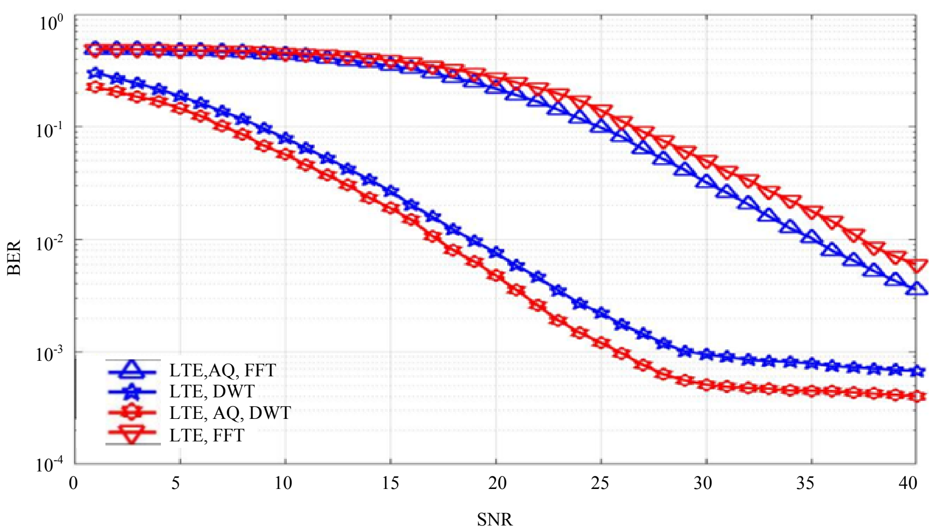

Fig. 13: LTE performance in selective fading channel-MDS = 50

that represents the selective channel is the Rayleigh distribution Model. The proposed system with FFT and FFT with neural network system and wavelets and wavelets with neural network system are tested under Maximum Doppler Shift (MDS) of values 5, 50, 200 Hz as shown in Fig. 12-14, respectivelly. From the figures mentioned, it is clearly that the proposed LTE based on MDS = 5 is much better than LTE based on MDS = 50 and MDS = 200.

In Fig. 12-14, it is found that the LTE system of wavelet with feed forward neural network (DWT-OFDM-FFNN) is better in performance than the other three systems that based on FFT and FFT-FFNN. In addition, the elimination of CP make the system with no extra cost in power and little lost in data rate and bandwidth.

LTE performance in specific LTE channel: 3 GPP Technical Recommendation (TR) defines three different types of multi-lane fading channels: Extended Pedestrians A (EPAs), Expanded Vehicular A (EVA) and Extended model Urbanization (ETU). These models enable the system to evaluate the performance of the proposed LTE transceiver in reference to multi-channel conditions. The model of any multipath fade channel can be defined by delay configurations and relative power relays. MDS is

Table 1: LTE channel Models (EPA, EVA, ETU) and delay profiles

Channel model	Excess tap delay (ns)	Relative power (dB)
Extended Pedestrian A(EPA)	[0, 30, 70, 90, 110, 190, 410]	[0, -1, −2, -3, -8, -17.2, -20.8]
Extended Vehicular A(EVA)	[0, 30, 150, 310, 370, 710, 1090, 1730, 2510]	[0, -1.5, -1.4, -3.6, -0.6, -9.1 ,-7, -12, -16.9]
Extended Typical Urban (ETU)	[0, 50, 120, 200, 230, 500, 1600, 2300, 5000]	[-1, -1, -1, 0, 0, 0, -3, -5, -7]

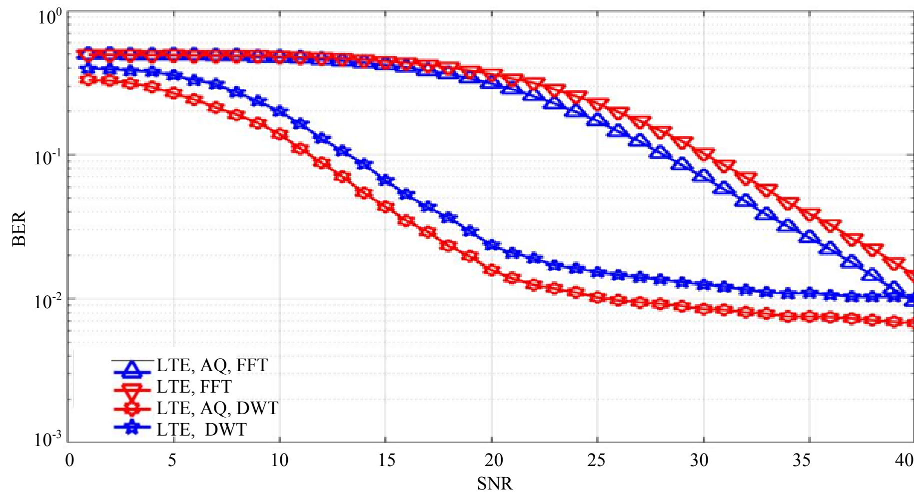

Fig. 14: LTE performance in selective fading channel-MDS = 200

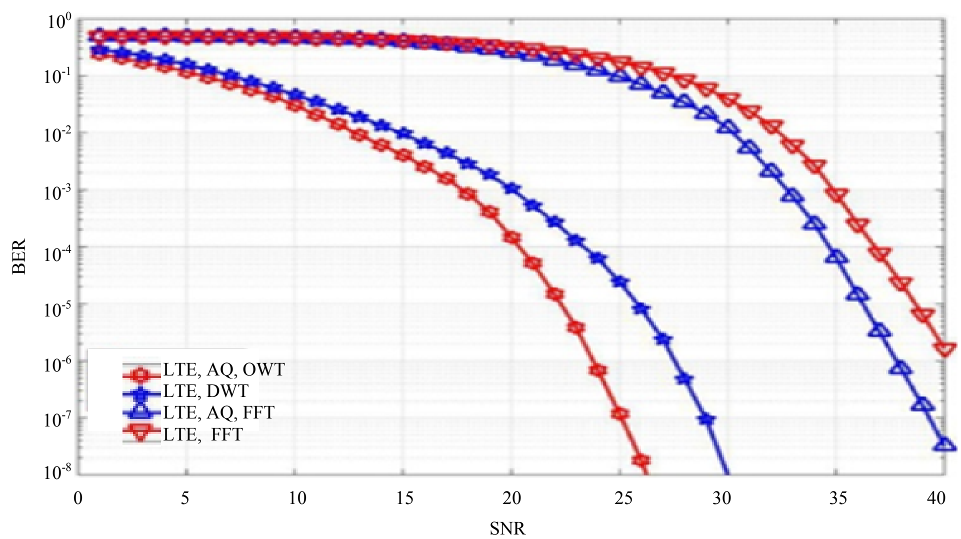

Fig. 15: LTE performance in EPA channel-MDS = 5

also determined with the data rate in the channel model. The delay profiles for these channel models are defined in low, medium and high environment delay propagation. Table 1 shows the channel delay profile for each model with values (Taps) in nano-second sand there relative power in dB (Shadmand *et al*., 2011).

The performance of the proposed system on the EPA channel model can be depicted in Fig. 15-17 for MDS = 5, 50, 200 Hz, respectively. It can be seen that the BER enhancement is accomplished by the proposed system against the traditional LTE.

The performance of the proposed system on the EVA channel Model can be seen in Fig. 18-20. It can also be seen that the proposed system enhances the BER against the SNR. Figure 21-23 shows the BER performance of the proposed LTE system under ETU channel conditions.

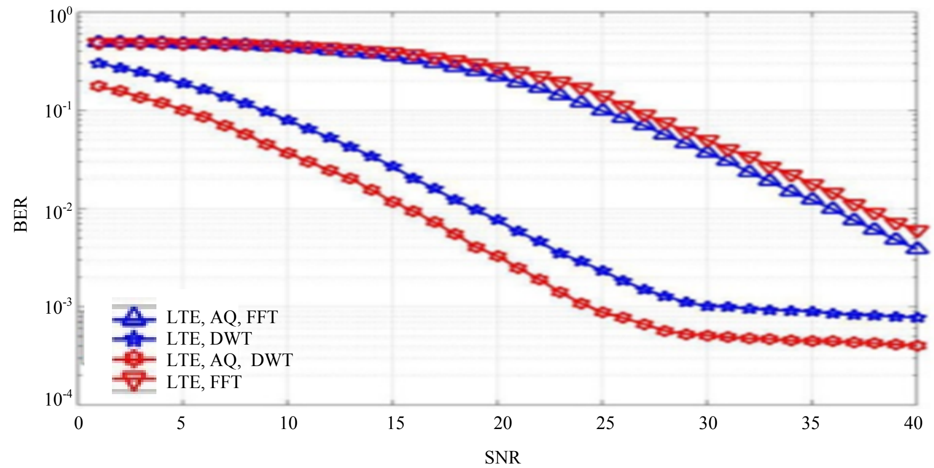

Fig. 16: LTE performance in EPA channel-MDS = 50

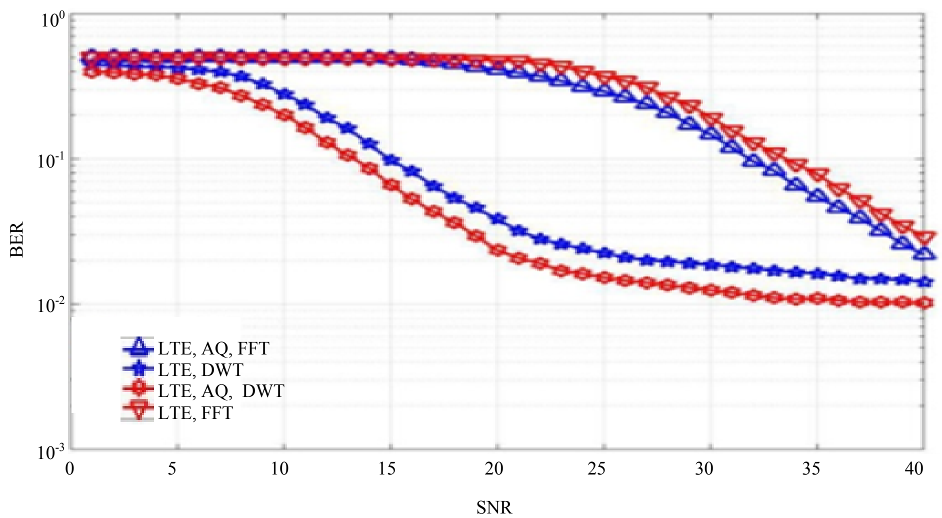

Fig. 17: LTE performance in EPA channel-MDS = 200

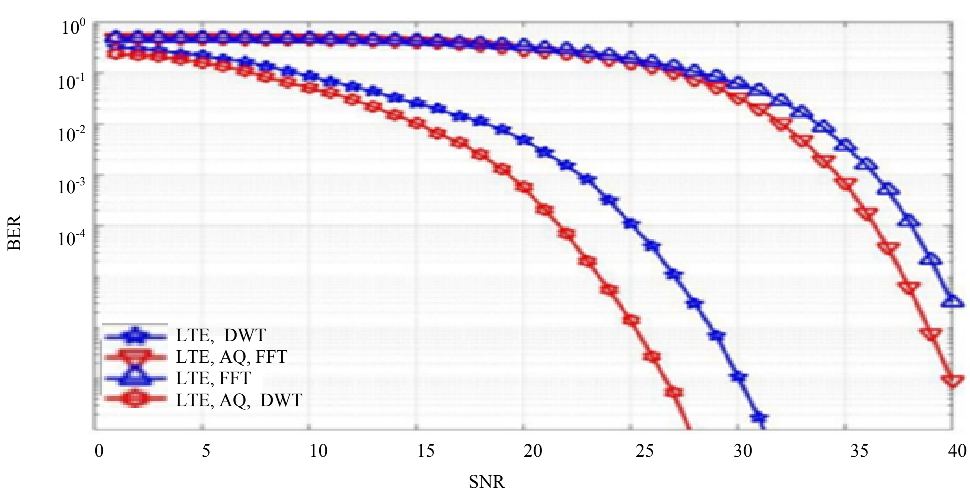

Fig. 18: LTE performance in EVA channel-MDS = 5

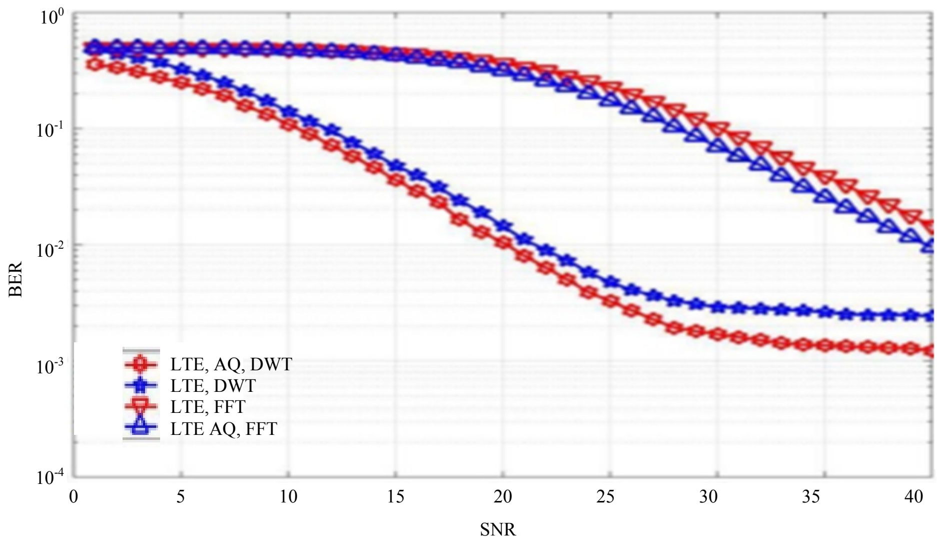

Fig. 19: LTE performance in EVA channel-MDS =50

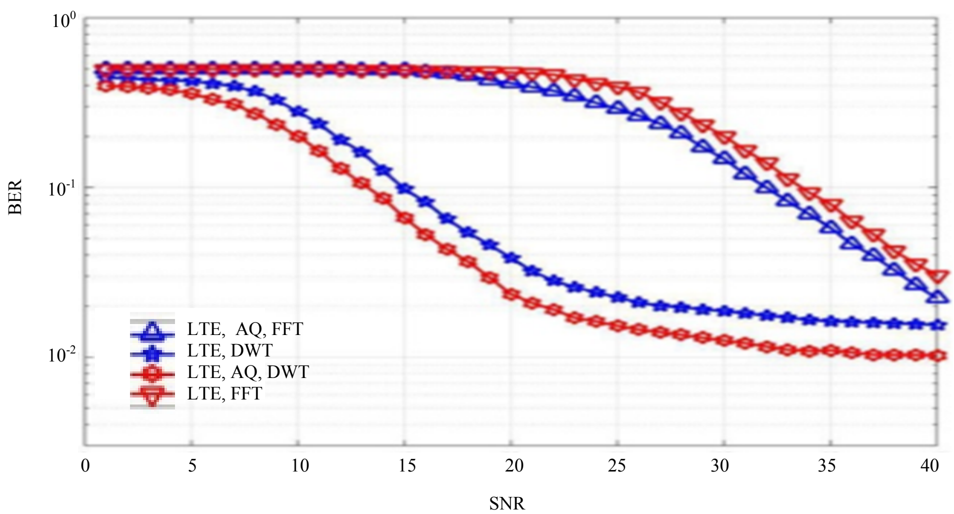

Fig. 20: LTE performance in EVA channel-MDS = 200

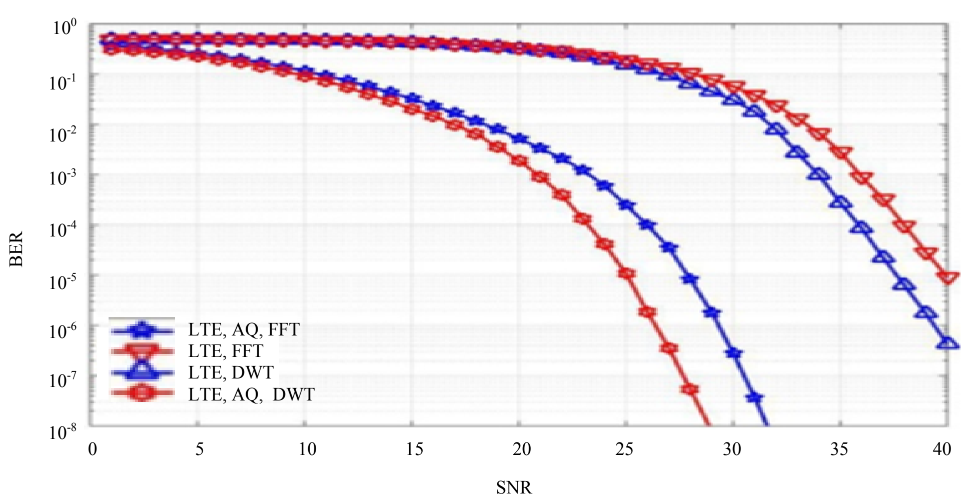

Fig. 21: LTE performance in ETU channel-MDS = 5

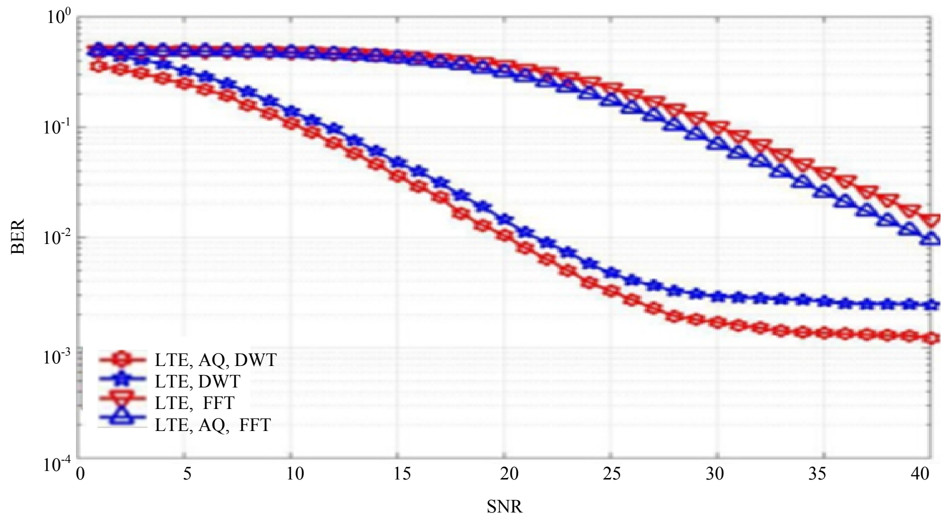

Fig. 22: LTE performance in ETU channel-MDS = 50

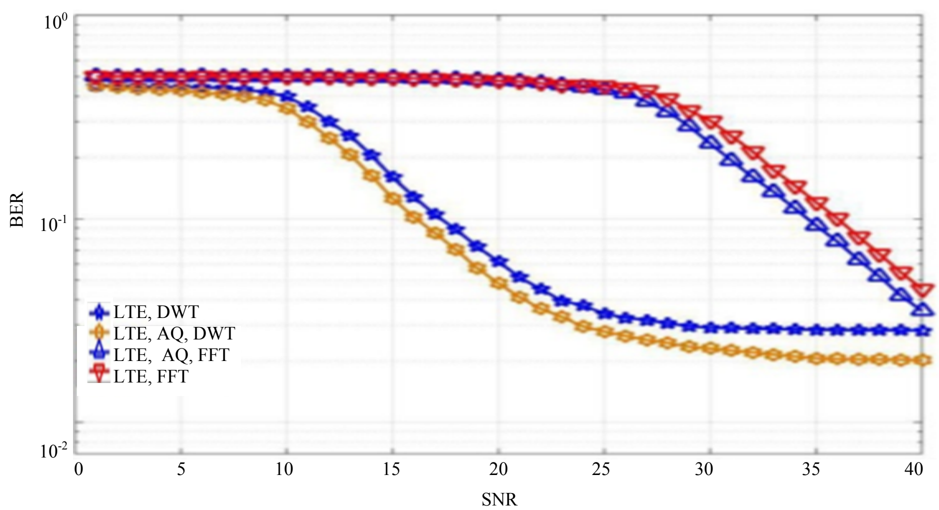

Fig. 23: LTE performance in ETU channel-MDS = 200

Here, as can be seen from Fig. 15-20 that the proposed DWT-LTE-FFNN has a better performance when testing on the EPA and EVA channel models than ETU Model. This conclusion can be seen clearly when compared the results with the performance at ETU channel as in Fig. 21-23.

The LTE system will be enhanced and the Bit Error Ratio (BER) will decrease due to the use of the neural network to make the system easier to adapt and reconstruct the channel output with respect to data entry.

CONCLUSION

The important results of this work tend to point to the fact that using the FFNN, so that, the LTE system will be enhanced and the BER will decrease due to the use of the neural network as an adaptive equalizer that makes the channel easier to adapt and reconstruct the output with respect to data entry. Wavelet-LTE is based on wavelet transform is tested for various variables in this study and compared with traditional LTE. It can be concluded that wavelets are a good choice for enhancing the BER performance for all channels also another advantage for the proposed system is the elimination of CP.

REFERENCES

Al-Thahab, O.Q.J., 2016. Speech recognition based radon-discrete cosine transforms by Delta Neural Network learning rule. Proceedings of the 2016 International Symposium on Fundamentals of Electrical Engineering (ISFEE), June 30-July 2, 2016, IEEE, Bucharest, Romania, ISBN:978-1-4673-9574-8, pp: 1-6.

Alli, I.P., 2012. Channel estimation in mobile wireless systems. Master Thesis, School of Electrical Engineering (EES), KHT Royal Institute of Technology Stockholm, Sweden.

Anusuya, P., K. Anitha and D.K. Varughese, 2013. Design of multiwavelet filter bank for 4G wireless communications. Proceedings of the 2013 International Conference on Communication and Signal Processing, April 3-5, 2013, IEEE, Melmaruvathur, India, pp: 847-852.

Batra, J., G.R. Balakrishnan, J. Aiello, R. Foerster and A. Dabak, 2004. Design of a multiband OFDM system for realistic UWB channel environment. IEEE Trans. Microwave Theory Tech., 52: 2123-2138.

Bhardwaj, M., A. Gangwar and D. Soni, 2012. A review on OFDM: Concept, scope & its applications. IOSR. J. Mech. Civil Eng., 1: 7-11.

Bingham, J.A.C., 1990. Multicarrier modulation for data transmission. An idea whose time has come. IEEE Commun. Mage., 28: 5-14.

Bouwel, C.V., J. Potemans, S. Schepers, B. Nauwelaers and A.V.D. Capelle, 2000. Wavelet packet based multicarrier modulation. Proceedings of the Joint IEEE Benelux Chapter on Vehicular Technology and Communications and Communications and Vehicular Technology (SCVT-2000) (Cat. No.00EX465), October 19, 2000, IEEE, Leuven, Belgium, pp: 131-138.

Chaturvedi, S., R.N. Titre and N. Sondhiya, 2014. Review of handwritten pattern recognition of digits and special characters using feed forward neural network and Izhikevich neural model. Proceedings of the 2014 International Conference on Electronic Systems, Signal Processing and Computing Technologies, January 9-11, 2014, IEEE, Nagpur, India, pp: 425-428.

Cho, Y.S., J. Kim and W.Y. Yang, 2010. Mimo-Ofdm Wireless Communications with Matlab. Wiley-IEEE Press, New York, ISBN-13: 978-0-470-82561-7, Pages: 544.

Daoud, O., 2012. Performance improvement of wavelet packet transform over fast Fourier transform in multiple-input multiple-output orthogonal frequency division multiplexing systems. IET. Commun., 6: 765-773.

Dawood, S.A., F. Malek, M.S. Anuar and H.A. Rahim, 2015. Enhancement the performance of OFDM based on multiwavelets using turbo codes. Telkomnika Telecommun. Comput. Electron. Control, 13: 1225-1232.

Haddadi, F., S. Khanchi, M. Shetabi and V. Derhami, 2010. Intrusion detection and attack classification using feed-forward neural network. Proceedings of the 2010 2nd International Conference on Computer and Network Technology, April 23-25, 2010, IEEE, Bangkok, Thailand, pp: 262-266.

Kattoush, A.H., W.A.M. Al-Jawher and O.Q. Al-Thahab, 2013. A radon-multiwavelet based OFDM system design and simulation under different channel conditions. Wireless Personal Commun., 71: 857-871.

Kumbasar, V. and O. Kucur, 2012. Performance comparison of wavelet based and conventional OFDM systems in multipath Rayleigh fading channels. Digital Signal Process., 22: 841-846.

Lavanya, R.V. and M. Madheswaran, 2014. Wimax (IEEE 802.16 m) system based on space time block code and discrete multiwavelet transform and implementation in FPGA. Telecommun. Syst., 56: 327-334.

Lindsey, A.R., 1995. Generalized orthogonally multiplexed communication via wavelet packet bases. Ph.D. Thesis, Ohio University, Athens, Ohio.

Linfoot, S.L., M.K. Ibrahim and M.M. Al-Akaidi, 2007. Orthogonal wavelet division multiplex: An alternative to OFDM. IEEE. Trans. Consum. Electron., 53: 278-284.

Ma, T.M., Y.S. Shi and Y.G. Wang, 2012. A low complexity MMSE for OFDM systems over frequency-selective fading channels. IEEE. Commun. Lett., 16: 304-306.

Negash, B.G. and H. Nikookar, 2000. Wavelet-based multicarrier transmission over multipath wireless channels. Electron. Lett., 36: 1787-1788.

Ohno, K., T. Ikebe and T. Ikegami, 2004. A proposal for an interference mitigation technique facilitating the coexistence of biphase UWB and other wideband systems. Proceedings of the 2004 Joint International Workshop on Ultra Wideband Systems and Ultra Wideband Systems and Technologies (UWBST & IWUWBS'04), (IEEE Cat. No.04EX812), May 18-21, 2004, IEEE, Kyoto, Japan, pp: 50-54.

Sakakibara, H., E. Okamoto and Y. Iwanami, 2005. A wavelet packet modulation method for satellite communications. Proceedings of the TENCON 2005, IEEE Region 10, November 21-24, 2005, IEEE Xplore London, pp: 1-5.

Sanjana, T. and M.N. Suma, 2014. Comparison of channel estimation and equalization techniques for OFDM systems. Circuits Syst. Int. J., Vol. 1, No. 1.

Shadmand, A., R. Dilmaghani, M. Ghavami and M. Shikh-Bahaei, 2011. Wavelet-based downlink scheduling and resource allocation for long-term evolution cellular systems. IET. Commun., 5: 2091-2095.

Shahriar, C., T.C. Clancy and R.W. McGwier, 2016. Equalization attacks against OFDM: Analysis and countermeasures. Wireless Commun. Mob. Comput., 16: 1809-1825.

Yan, X. and G. Liu, 2004. Multiwavelet packet based OFDM system. Proceedings of the 2004 IEEE Asia-Pacific Conference on Circuits and Systems Vol. 2, December 6-9, 2004, IEEE, Tainan, Taiwan, pp: 681-684.