Comparison of Performance AWGN, Rician and Rayleigh Channel for HIPERLAN/2 system for to reducing Non-linearity using Neural Network

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Abstract

Simulation of ETSI's High Performance Local Area Network Type 2(HIPERLAN/2) is presented. In this paper we present performance of HIPERLAN/2 model via a MATLAB/Simulink simulation with the original MATLAB/Simulink model and the model using Neural Networks LVQ (Linear Vector Quantization) algorithm. MATLAB/Simulink modeling demonstrates that the performance of HIPERLAN/2 with Neural Network reduces the Nonlinearity of the original model to a great extent.

Index Terms— AWGN, HPA, HIPERLAN/2, LVQ, Nonlinearity, Neural Network, OFDM, Rician, Rayleigh, Saleh.

1. Introduction

Higher data in wireless communication can be achieved by increased or more efficient use of bandwidth, and transmitted power. A key technique for spectral optimization is orthogonal frequency division multiplexing (OFDM). The European Telecommunication Standards Institute(ETSI) and IEEE have proposed OFDM for high speed wireless LAN and its being consider for 4G mobile. ETSI's proposed HIPERLAN/2 standard describes the Physical (PHY) layer based on OFDM technology and the data rate of HIPERLAN/2 ranges from 6 to 54 Mbits/sec depending on Quality of Service (QoS). It is designed to provide Wireless Local Loop (WLL) to core networks, e.g. Asynchronous Transfer Mode, GSM/UMTS or any IP-based multimedia network. The link adoption scheme automatically determines the data rate, coding rate and modulation type depending on the channel conditions.
The HIPERLAN/2 system with original 16QAM modulation has high nonlinearity due to which the signal at the receiver end introduce scattering in the signal. The cause of nonlinearity is High Power Amplifier (HPA) in HIPERLAN/2 system. The amplifier can consume a major fraction of the power used by the system; both the required transmit power and loss associated with amplifier inefficiency. The power amplifier can also distort the transmitted signal, introducing addition noise within the signal frequency band and generating unwanted frequencies in adjacent channels. Also a major disadvantage of OFDM i.e. PAPR (Peak to Average Power Ratio) also introduce nonlinearity by high peaks of PAPR, causing inter-modulation among subcarriers and undesired out-of- band radiation. [1]

The Neural Network algorithm of Linear Vector Quantization (LVQ) used in the Receiver section of HIPERLAN/2 reduces the non-linearity of the system to great extent for three different channels.

A. Theory of ofdm

In OFDM high-rate data-stream are split into multiple lower rate streams and transmitted simultaneously using different subcarriers. Individual groups of bits (symbols) modulate mutually orthogonal subcarriers. An inverse fast Fourier transform (IFFT) block converts the frequency domain signals(e.g. QAM,BPSK, QPSK symbols) into a time domain (sum of sinusoids) and the process is reversed at the receiver. Correlation with every basis function using an FFT determines the energy for each subcarrier. Since subcarriers are uncorrelated their spectra can overlap (enhancing spectral efficiency) without causing inter-carrier interference (ICI). Delay spread (DS), the time difference between the first and last reception of the same symbol due to multipath effects in the channel, cause Inter-symbol Interference (ISI). Hence guard times are required to separate successive OFDM symbols, but contain no information and waste energy. The duration of OFDM symbol is usually chosen to be six times the guard time to make the concomitant loss smaller than 1 dB. The guard time must contain cyclically extended symbol to prevent ICI occurring due to loss of orthogonality. The complex envelope of OFDM signal can be written as,

$$x(t) = \sum_{n=-N/2}^{\frac{N}{2}-1} \sum_{-\infty}^{\infty} a_n(i) s_n(t - iT') \qquad (1)$$

Where $T' = T + Tg$ is the OFDM symbol period, N is the number of subcarriers and is the guard period a_n is the emitted symbol in the ith time slot on the nth sub-channel,

$s_n(t) = \sqrt{2\varepsilon / T'} \; e^{j2\pi f_n t}, \; -T_g \leq t <$ Where ε is the transmitted pulse energy

II. HPA

High power amplifiers are an important component of in modern communications system, providing the transmit signal level needed to overcome the loss between the transmitter and receiver. However they also introduce problems. The amplifier can consume major fraction of the power used by the system; both the transmitted power and loss associated with amplifier inefficiency. The power amplifier can also distort the transmitted signal, introducing additional noise within the signal frequency band and generating unwanted frequencies in adjacent channels. Amplifiers usually operate as a linear device under small signal conditions and become more nonlinear and distorting with increasing drive level. The amplifier efficiency also increases with increased output power, thus, there is a system level tradeoff between the power efficiency or battery life and resulting distortion. For most commercial system the tradeoff is constrained by interference with adjacent users, thus, amplifier signal level are reduced or “backed off” from the peak efficiency operating point.

A. HPA Models

Several HPA models are available, mainly for two types of amplifiers. One is known as Travelling Wave Tube Amplifier (TWTA) and another is Solid- State Power Amplifier (SSPA). The models developed so far can mainly be divided in two categories. One exhibit nonlinear distortion in both amplitude (AM/AM) and phase (AM/PM).Other exhibit nonlinear distortion in amplitude (AM/AM) only.

B. TWTA Model

The most widely used model for TWTA is known as Saleh model. It considers nonlinear distortion in both amplitude (AM/AM) and phase (AM/PM). The model is extensively used in nonlinear distortion analysis related to OFDM system [2]. In Saleh model, input signal is defined by the equation as

$$x(t) = r(t).\cos[\omega_0 t + \psi(t)] \qquad (2)$$

Where ω_0 is the carrier frequency, *r(t)* and *ψ(t)* are modulated envelope and phase respectively. The corresponding output in equation can be written as

$$y(t) = A[r(t)].\cos\{\omega_0 t + \psi(t) + \Phi[r(t)]\} \qquad (3)$$

Where *A(r)* is an odd function *r*, with the linear leading term representing AM/AM conversion and *Φ(r)* is an odd function of *r*, with a quadratic leading term representing AM/PM conversion.

C. Hiperlan/2

The OFDM system used in HIPERLAN/2 provides a WLAN with data payload communication capabilities of 6, 9, 12, 18,24,36,48 and 54 Mbps [3]. The system uses 52 carriers that are modulated using binary or quadrature phase shift keying (BPSK/QPSK), 16-quadrature amplitude modulation (QAM), or 64 QAM. Forward error correction coding (Convolution coding) is used with a coding rate of 1/2, 2/3 or 3/4. At the transmitter, binary input data is encoded by the industry standard rate 1/2, constraint length 7 and code with generator polynomials (133, 171) [4]. Optional puncturing omits some of the encoded bits in the transmitter, increasing the bit rate to 2/3 or 3/4. Interleaving with a block size corresponding to the number of bits in OFDM symbols reduces the effect of frequency selective fading in the radio channels. It also prevent error bursts from being input to the convolution decode process in the receiver. After interleaving the bits are mapped into complex number according to the modulation scheme which is normalized to achieve the same average power for all mappings. In order to facilitate coherent reception, four pilot values are added to each of 48 data values, such that a total of 52 modulation values are reached per OFDM symbols. 52 values are then modulated on to 52 subcarriers by applying an Inverse Fast Fourier Transfer (IFFT). The IFFT converts all the mapped symbols of the frequency domain into time domain signal for transmission. A guard interval (cyclic prefix) is added to make the system robust to multipath propagation and is used for both timing and frequency synchronization. Next windowing is applied to attain a narrower output spectrum. The modulated and windowed digital output signal are converted to analog signals, which are then up converted to the proper channel in the 5 GHz band, amplified and transmitted through an antenna.

A typical OFDM receiver basically performs the reverse operations of the transmitter, together with additional training tasks. First the receiver has to estimate the frequency offset and symbol timing, using special training symbols in the preamble. Then it can do the Fast Fourier Transform (FFT) for every OFDM symbol to recover 52 modulation values of all subcarriers. The training symbols and pilot subcarriers are used to correct for the channel response as well as any remaining phase drift. The time domain signal is converted into frequency domain by the FFT and symbols are extracted by a QAM (QPSK or BPSK) demodulator. Removal of pilot carriers, frame synchronization and elimination of cyclic prefixes are performed before hand in the receiver block. After demoralization, frames are passed through a e-interleaving process and finally the received data bits are compared to the transmitted bits by a bit error calculator. Decoding of the convolution code is implemented by means of Viterbi decoder that can be used to decode the information sequence with a trace back path of 34.

D. Neural Network And Vector Quantization Algorithm

Artificial Neural Networks are widely used in Computer Science and its applications thus there are several type of networks for specific problems. A neural network consists of numerous computational elements (neurons or nodes) highly interconnected to each other. A weight is associated with every connection. Normally nodes are arranged into layers. During a training procedure input vectors are presented to the input layer with or without specifying desired output.

A. LVQ

The Learning Vector Quantization algorithm belongs to the field of Artificial Neural Networks and Neural computation. The learning Vector Quantization algorithm is a supervised neural network that uses a competitive (winner-take-all) learning strategy. It is related to the other supervised neural networks such as the Perceptron and the Back-propagation algorithm. It is related to other competitive learning neural networks such as the Self-Organizing Map algorithm that is a similar algorithm for unsupervised learning with addition of connections between the neurons.

An LVQ network has a first competitive layer and a second linear layer. The linear layer transforms the competitive layer's classes into target classifications defined by user. The classes learned by the competitive layer are referred to as *subclasses* and classes of the linear layer as *target classes*.

B. AWGN Channel

Additive White Gaussian noise (AWGN) is a channel model in which the only impairments to communication is a linear addition of wideband or white noise with a constant spectral density and a Gaussian distribution of amplitude. AWGN channel is good model for many satellite and deep space communication links. It is not good model for most terrestrial links because of multipath, terrain blocking, interfaces etc.

B. Rician Channel

Rician fading is a stochastic model for radio propagation anomaly caused by partial cancellation of radio signal by itself – the signal arrives at the receiver by several different paths and at least one of the paths is changing (lengthening or shortening).

Rician fading occurs when one of the paths, typically line of sight, is much stronger
Than others.In Rician fading, the amplitude gain is characterized by a Rician distribution.

A Rician fading channel can be described by two parameters: K and Ω. K is the ratio between power in the direct path and power in the other scattered, path. Ω is the total power from both paths ($\Omega = \nu 2 + 2\sigma 2$) and acts as a scaling factor to the distribution.

C. Rayleigh Channel

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal such that used in wireless devices. Rayleigh fading model assume that the magnitude of a signal that has passed through such a transmission medium will vary randomly, or fade according to Rayleigh distribution – the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may not be applicable.

Rayleigh fading is more reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficient much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distribute between 0 and 2π radians. The envelope of the channel response will be therefore Rayleigh distributed.

E. Simulation setup

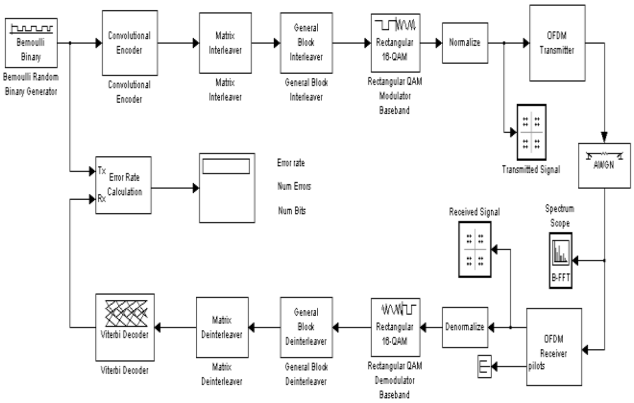


Fig. 1 Block diagram of HIPERLAN/2 with AWGN channel

Fig.1 .shows the original 16QAM model of the HIPERLAN/2 .The Saleh model of Travelling Wave Tube Amplifier is selected as a HPA model in the system and it is connected after the OFDM transmitter. HPA's are used to amplify the power of the signal before sending it on the channel. This block of HIPERLAN/2 with Saleh amplifier is shown in fig. 2. Fig. 3 represent block of HIPERLAN/2 with Linear Vector Quantization (LVQ) Neural Network. Here the Neural network block is trained using LVQ algorithm for 48 sub-carriers. The network is generated using the data of OFDM transmitter and Receiver.

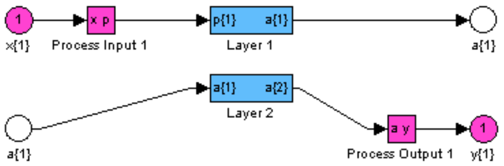


Fig.2. LVQ Neural Network Simulated Architecture

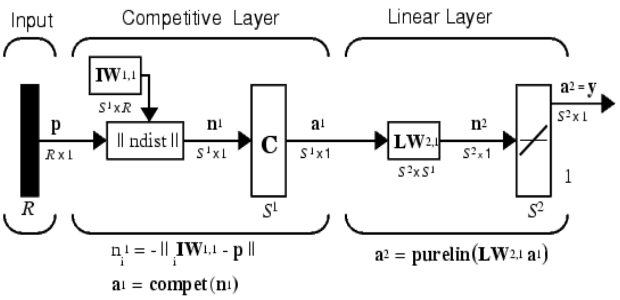


Fig.3. LVQ Neural Network Theoretical Architecture

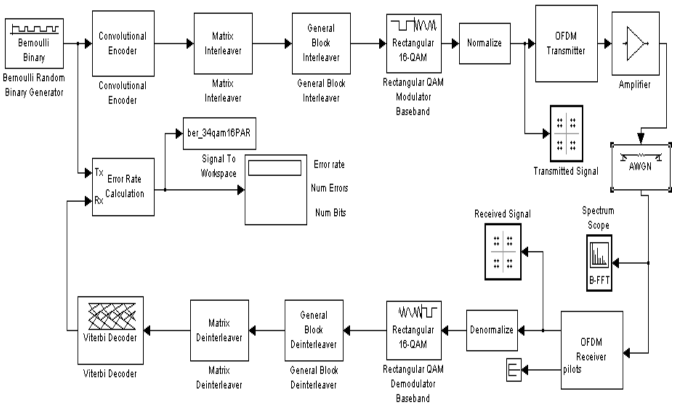


Fig. 4. Block diagram of HIPERLAN/2 with HPA with AWGN

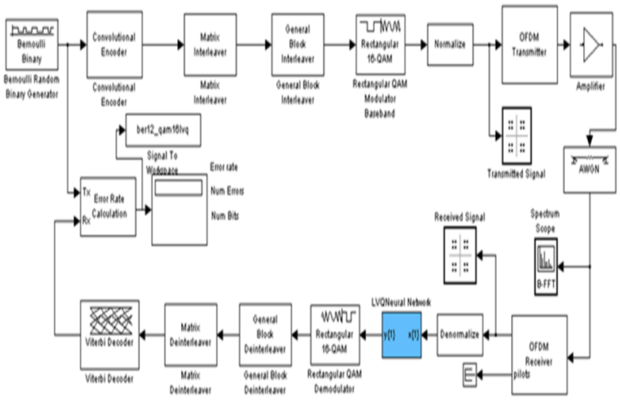
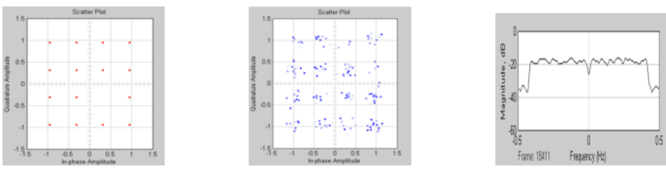


Fig.5. Block diagram of HIPERLAN/2 with LVQ Neural Network with AWGN Channel

III. Result

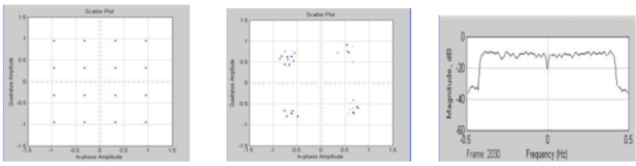
In this section we present some simulation results showing the performance of HIPERLAN/2 with original 16QAM model, with Saleh amplifier and with LVQ Neural Network.The BER plots for HIPERLAN/2 are also shown.



(a) Transmitted signal (b) Received signal (c) Spectrum plot

Fig.6.Simulation result of HIPERLAN/2 without HPA and Neural Network with AWGN channel.

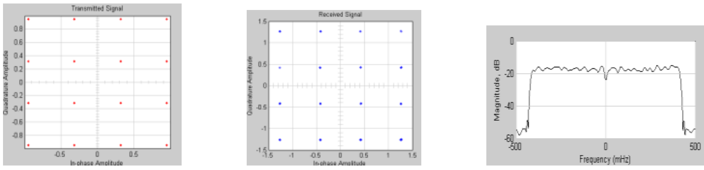
Fig. 6(a) and (b) shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 for original 16QAM model with AWGN channel. In original model the received constellation points are more scattered and signal is also degraded.



(a) Transmitted signal (b) Received signal (c) Spectrum plot

Fig.7 Simulation result of HIPERLAN/2 with Saleh Amplifier with AWGN channel

Fig 7(a) and (b) shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 with Saleh model of HPA. After including amplifier in the system, an effect of nonlinearity can be seen on the received constellation points. The received signal is more scattering.



(a) Transmitted signal (b) Received signal (c) Spectrum plot

Fig.8.Simulation result of HIPERLAN/2 with Saleh amplifier and LVQ Neural Network with AWGN channel

Fig 8(a) and (b) shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 with Saleh amplifier and LVQ Neural Network. Using trained neural network with the data of HIPERLAN/2 and connecting it in the receiver section of HIPERLAN/2 reduces the nonlinearity of original system to a great extent. From fig it can be seen received constellation points are having nearly zero scattering and the spectrum plot is good in nature.

A graph showing the Signal to Noise ratio (SNR) plotted against the Bit Error Rate (BER) is shown in figure 9. The cyan curve represents the original system response, whereas red and green curve represent the response of the system after passing through HPA and LVQ respectively. With Saleh model BER of the system is 0.5020 for SNR =1dB. Whereas with LVQ at SNR =1dB BER is 0.5012 i.e. the error rate is reduced.

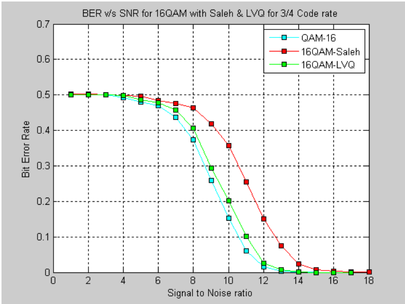
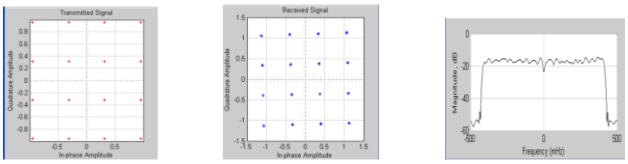


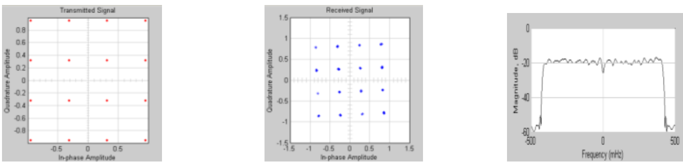
Fig. 9. BER vs. SNR plot of Simulation result of HIPERLAN/2 for 16qam with Saleh amplifier and LVQ Neural Network with AWGN channel.



(a) Transmitted signal (b) Received signal (c) Spectrum plot

Fig.10. Simulation result of HIPERLAN/2 with Saleh Amplifier with Rician channel.
Fig. 10(a) and (b) shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 for original 16QAM model with Rician channel. It can be seen from the result that the received signal constellation points are not scattered and the signal is also beam oriented.

Fig. 11(a) and (b) shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 for original 16QAM model with Rayleigh channel. It can be seen from the result that with this channel also the received signal constellation points are not scattered and the signal is also beam oriented. Only the difference can be seen that the received signal constellation is nearer to other. The Rayleigh channel has effect of phase noise. The channel parameters are to be adjusted to reduce the effect of phase noise.



(a) Transmitted signal (b) Received signal (c) Spectrum plot

Fig.11.Simulation result of HIPERLAN/2 with Saleh Amplifier with Rayleigh channel.

A. Conclusion

In this paper, the effect of HPA and LVQ Neural Network on HIPERLAN/2 with AWGN, Rician and Rayleigh channel has been analyzed. We can conclude that using a trained LVQ Neural Network in the receiver section of HIPERLAN/2 the effect of nonlinearity on HIPERLAN/2 system reduces to a great extent in all channels.

B. References

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