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Abstract- HIPERLAN/2 performance analysis via a MATLAB/Simulink simulation is present. This paper shows the results of simulations performed on a MATLAB/Simulink model HIPERLAN/2 system with and without a nonlinear power amplifier for AWGN channel. In the following analysis, an additive white Gaussian (AWGN) transmission channel is assumed since attention is focused on the effects on the nonlinearity. The power amplifier model used here is the Rapp’s Solid State Power Amplifier (SSPA) model. Here we showed that HIPERLAN/2 is much more sensitive to power amplifier nonlinearities. The paper shows that the received constellation points are considerably distorted after passing through the amplifier. The BER plot is more degraded when the transmitted signal passes through the amplifier than the plot when it does not pass through the amplifier.

Keywords- *OFDM, HIPERLAN/2, nonlinearity, Rapp’s model, BER performance*

I. INTRODUCTION

The European Telecommunication Institute (ETSI) High Performance Local Area Network Type2 (HIPERLAN/2) is a system designed to give wireless access to the Internet and multimedia applications such as real time video, providing speeds up to 54 Mbps. Being a quick and easily set system and providing internetworking with several core networks including the Ethernet, HIPERLAN/2 has many application areas and features such as transmission capability at high speeds, quality of service support, automatic frequency allocation, mobility and security support and a connection-oriented link. The HIPERLAN/2 standard is based on orthogonal frequency division multiplexing (OFDM), which is an efficient technology that splits up the available bandwidth among several closely spaced, mutually orthogonal subcarriers. By using a guard period or a cyclic prefix, OFDM transmission converts an intersymbol interference (ISI) channel into many parallel flat fading channels.

The HIPERLAN/2 baseband signal consists of OFDM symbols with 48 data carriers and 4 pilot carriers. The data carriers are modulated with either BPSK, QPSK, QAM16 or

QAM64.The uncoded bit rate increases with the modulation scheme and is 12, 24, 48 or 72Mbit/s respectively.

Parameter	HIPERLAN/2
Band	5.15 – 5.725 GHz
Data Rate	6, 9,12,18, 24, 36, 48, 54Mbit/s
Code Rate	½, 9/16, 3/4, 2/3
Number of Subcarriers	52
Number of Pilot Tones	4
Guard Interval	800 η sec , 400 η sec (optional)
Subcarrier Spacing	312.5kHz
Channel spacing	20 MHz
Subcarrier modulation	BPSK, QPSK, QAM16 or QAM64
Normal bitrate (no FEC)	12 – 72 Mbit/s
Frame duration	2ms
Symbol duration	4 μs

II. OFDM THEORY

In OFDM, high-rate data-streams 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,QPSK,BPSK symbols) into a time domain signal (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 intercarrier 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, causes intersymbol interference (ISI). Hence, guard times are required to separate successive OFDM symbols, but contain no information and waste energy. The duration of an 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 the OFDM signal can be written as

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

where $T' = T + T_g$ is the OFDM symbol period, N is the number of subcarriers, and T_g is the guard period, $a_n(i)$ is the emitted symbol in the ith time slot on the nth subchannel, $s_n(t) = \sqrt{2\varepsilon/T'}\, e^{j2\pi f_n t}, -T_g \le t < T$, where ε is the transmitted pulse energy

An OFDM signal is the sum of sinusoidal wave and transmits as multicarrier so that the peak power of OFDM signal increases in proportion to the number of subcarriers. As a result, multicarrier systems are more sensitive than the single-carrier systems to the presence of nonlinearities when such a signal is input to a nonlinear amplifier. Nonlinear distortions are primarily due to the transmitter high-power-amplifier (HPA), which must be driven as close to its saturation point as possible in order to make its operation power efficient. The nonlinear effects on the transmitted OFDM signal are spectral-spreading of the OFDM signal, intermodulation effects on the subcarriers, warping of the signal constellation in each subchannel. The nonlinear distortion causes some interference both inside and outside the signal bandwidth. The in-band component determines a degradation of the system bit-error rate (BER), whereas the out-of-band component affects adjacent frequency bands.

III. HPA MODEL

Several HPA models are available in the literature mainly for two types of amplifiers. One is relatively older & is known as Traveling Wave Tube Amplifier (TWTA) that exhibits nonlinear distortion in both amplitude (*AM/AM*) and phase (*AM/PM*). Other is Solid State power Amplifier (SSPA) that exhibits nonlinear distortion in amplitude (*AM/AM*) only. In this paper, we consider a solid-state power amplifier (SSPA) without AM/PM conversion. SSPA have been chosen due to some of its distinct advantages such as no warm up time requirement, inherently good linear performance for multicarrier, digital transmission, built in soft-fail capabilities in case of single device or module failure, no expected RF section sparing requirements, high volume production capability.

For SSPA, nonlinear distortion has been analyzed using Rapp's Model. This HPA model is simulated using the following relation considering distortion in amplitude only.

$$A[\rho(t)] = \frac{\rho(t)}{\left[1 + \left(\frac{\rho(t)}{A_0}\right)^{2p}\right]^{\frac{1}{2p}}}$$

$$\Phi[\rho(t)] = 0$$

Here $A[\rho(t)]$ and $\Phi[\rho(t)]$ represent the AM/AM and AM /PM conversion characteristics of the nonlinear amplifier, A_0 is the maximum output amplitude and the parameter *p* controls the smoothness of the transition from the linear region to the limiting region. A good approximation of existing HPA can be obtained by choosing *p* in the range of 2 to 3. For large values of *p*, the model converges to a clipping amplifier and is perfectly linear until it reaches the maximum output power level. This is however very hard to achieve in practical system.

The operating point of the amplifier is usually identified by the "backoff". The effects of the nonlinearities can be reduced by working with high backoff, which corresponds to moving the operating point of the amplifier to the linear region. Unfortunately, this leads to a loss in power efficiency of the HPA. In the time domain, the nonlinear distortion of the transmitted signal generates a noise distortion signal spread in the frequency domain over each carrier.

IV. SIMULATION SETUP

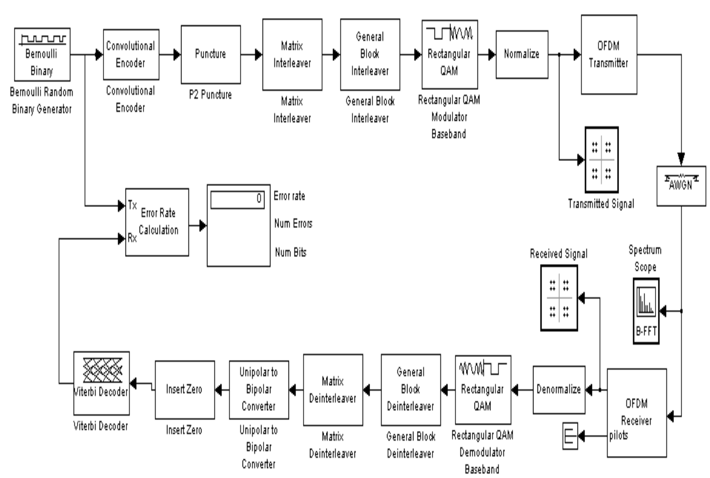


Fig.1.HIPERLAN/2 simulation setup without SSPA (Rapp's model)

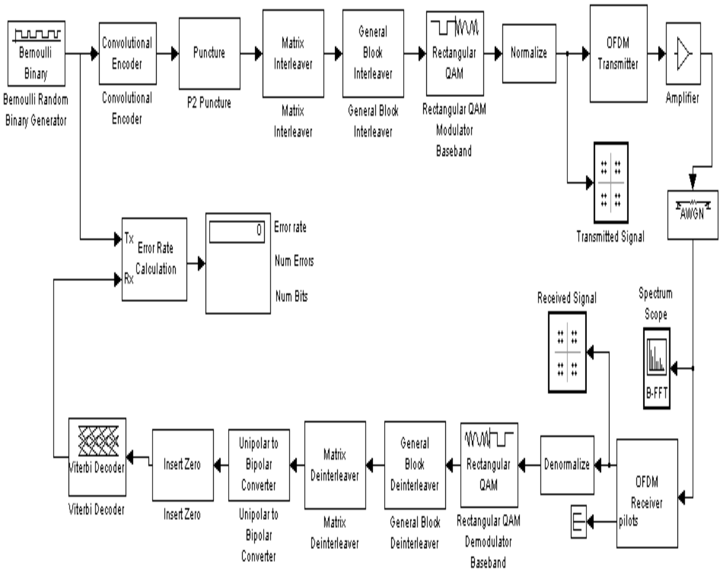


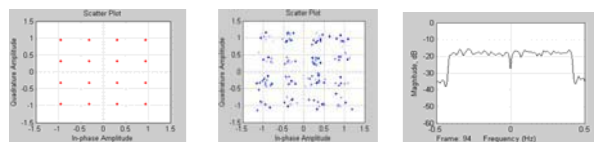
Fig.2.HIPERLAN/2 simulation setup with SSPA (Rapp's model)

The block diagram of the simulation setup for HIPERLAN/2 without Rapp's Solid State Power Amplifier model is shown in the fig.1. In our transceiver model, binary data bits are generated and then channel coded by a convolutional encoder. The forward error correction code rate is normally 1/2. Optional puncturing omits some of the encoded bits in the transmitter, increasing the bit rate, and inserts a dummy 'zero' metric into the convolutional decoder on the receiver side in place of omitted bits The 1/2 code rate can be increased to 2/3, 3/4 or 9/16 by a suitable puncturing code. Interleaving, with a block size corresponding to the number of bits in an OFDM symbol, reduces the effect of frequency selective fading in the radio channels. It also prevents error bursts from being input to the convolutional decode process in the receiver. Binary values are then mapped to QAM (BPSK, QPSK) symbols, which are normalised to achieve the same average power for all transmission mappings. The IFFT converts all the mapped symbols in the frequency domain into a time domain signal for transmission.

Zero padding (the addition of extra zero bits in the OFDM symbol) is used to avoid aliasing. Cyclic prefixing can be implemented by adding the last few bits of a symbol at the beginning of the symbol and is used for both timing and frequency synchronisation. On the receiver side, most of the functions are just the opposite of the equivalent transmitter blocks. The time domain signal is converted into the 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 beforehand in the receiver block. After denormalisation, frames are passed through a de-interleaving process. Viterbi algorithm is used to decode convolutionally encoded input data. With the Viterbi algorithm, the zero-valued dummy bit has no effect on the outcome of the decoder. Finally the received data bits are compared to the transmitted bits by a bit error calculator.

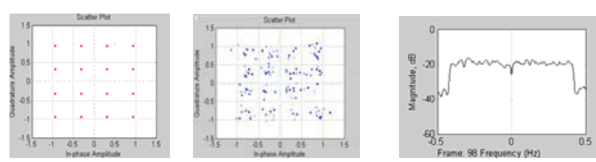
The block diagram of the simulation setup for HIPERLAN/2 with Rapp's Solid State Power Amplifier model is shown in the fig.2. In this setup, we had connected an amplifier model just after OFDM transmitter block in the transmitter. The amplifier gives rise to nonlinearities which affects the constellation points of the 16QAM modulator in the transmitter. These nonlinearities then pass to the receiver and degrade the received signal. The same setup can be used with BPSK and QPSK modulator – demodulator pair in place of 16QAM modulator – demodulator pair.

V. RESULT



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

Fig.3. Simulation result of HIPERLAN/2 for 16QAM without Rapp's model



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

Fig.4. Simulation result of HIPERLAN/2 for 16QAM with Rapp's model

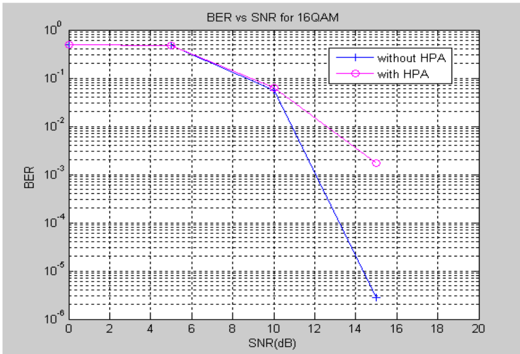


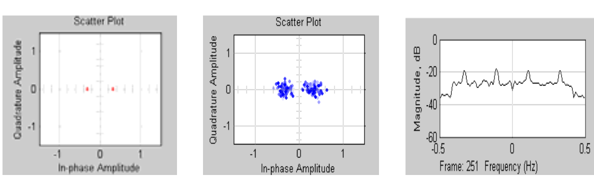
Fig.5. BER Vs SNR Plot of HIPERLAN/2 for 16QAM without and with Rapp's model

In this section we present some simulation results showing the distortion in the received signal when the transmitted signal passes through the amplifier for 16QAM, BPSK and QPSK modulations. The BER plots for HIPERLAN/2 without and with Rapp's model are also shown.

Figures 3(a) and (b) shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 for 16QAM before passing through the Rapp's model . Here it can be seen the received constellation points are less distorted when it does not pass through the amplifier.

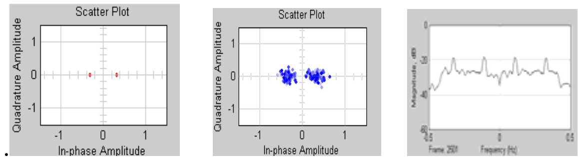
Figures 4(a) and (b) below shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 for 16QAM after passing through the Rapp's model. As can be seen, considerable distortion takes place in the received constellation points when the transmitted signal passes through the amplifier. This shows that the modulation scheme used is more sensitive to amplifier nonlinearities. The spectrum of the signal after the nonlinearity is wider than before the nonlinearity.

A graph showing the Signal to Noise ratio (SNR) plotted against the Bit Error Rate (BER) is shown in the figure 5. Here it can be seen that the curve for HIPERLAN/2 with Rapp's SSPA model is much more degraded than the curve without SSPA.



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

Fig.6. Simulation result of HIPERLAN/2 for BPSK without Rapp's model



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

Fig.7. Simulation result of HIPERLAN/2 for BPSK with Rapp's model

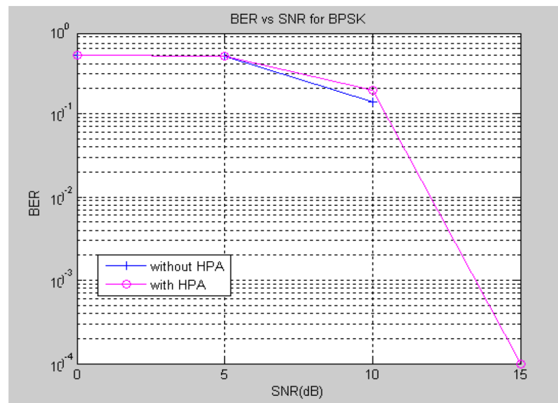
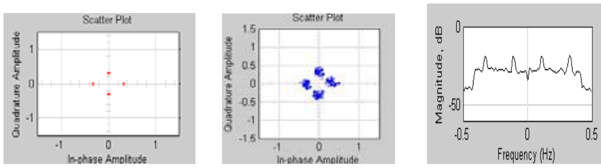


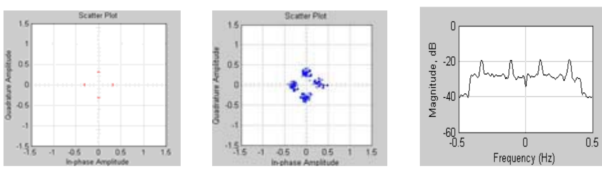
Fig.8. BER Vs SNR Plot of HIPERLAN/2 for BPSK without and with Rapp's model

Figures 6(a) and (b) shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 for BPSK before passing through the Rapp's model. Here it can be seen the received constellation points are less distorted when it does not pass through the amplifier. Whereas figures 7(a) and (b) below shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 for BPSK after passing through the Rapp's model. As can be seen, considerable distortion takes place in the received constellation points when the transmitted signal passes through the amplifier. The spectrum of the signal after the nonlinearity is wider than before the nonlinearity. A graph of Signal to Noise ratio (SNR) is plotted against the Bit Error Rate (BER) which is shown in the figure 8. Here it can be seen that the curve after passing through the amplifier. is much more degraded than the curve without amplifier.



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

Fig.9. Simulation result of HIPERLAN/2 for QPSK without Rapp's model



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

Fig.10. Simulation result of HIPERLAN/2 for QPSK with Rapp's model

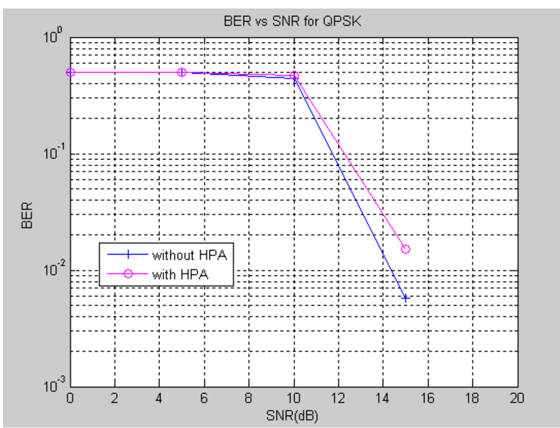


Fig.11 BER Vs SNR Plot of HIPERLAN/2 for QPSK without and with Rapp's model

The transmitted and received signals are shown in figures 9(a) and (b) shows and fig(c) shows the spectrum plot of HIPERLAN/2 for QPSK before passing through the Rapp's model. Figures 10(a) and (b) below shows the transmitted and received signals and (c) shows the spectrum plot of HIPERLAN/2 for QPSK after passing through the Rapp's model. As can be seen, considerable distortion takes place in the received constellation points when the transmitted signal passes through the amplifier as compared to the received constellation points when it does not pass through the amplifier. The spectrum is much wider after the signal passes through nonlinear amplifier. The Signal to Noise ratio (SNR) verses the Bit Error Rate (BER) is shown in the figure 11. Here it can be seen that the curve for HIPERLAN/2 with Rapp's SSPA model is much more degraded than the curve without SSPA.

VI. CONCLUSION

. We have developed a closed-form theory to characterize the nonlinear distortions induced on an OFDM signal by an HPA. In this paper, the effects of nonlinearities in the power amplifier over HIPERLAN/2 system for 16QAM, BPSK and QPSK were analyzed. Besides spectral spreading of the OFDM signal, warping and clustering of the signal constellation occur in each subchannel at the output of the amplifier. We can conclude that nonlinear power amplifier reduced dramatically the performance of the system. By the use of nonlinear amplifier, linear amplification to saturated amplitude is possible. The received constellation points were considerably distorted. Nonlinear distortion generates a cluster of received values around each constellation point, in place of a single one. The spectrum of the signal out from the nonlinearity was somewhat wider than the input. The BER curve for HIPERLAN/2 with Rapp's SSPA model was much more degraded than the curve without SSPA. Non-linear amplification destroys the orthogonality of the OFDM signal and introduces out-of-band radiations.

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