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Distortion level approximation of Linear and Nonlinear RF Power Amplifier over OFDM System

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ABSTRACT

Peak to average power ratio (PAPR) has become a major concern in multi-carrier-Orthogonal Frequency Division Multiplex (OFDM) application. The PAPR in OFDM transmitter causes efficiency reduction of RF power amplifier. Several mitigation approaches have been proposed in the literature for the OFDM system. Most of these approaches suffer from lack of high PAPR performance or complexity. In this paper, some of the most significant features of OFDM such as cyclic prefix, spectral efficiency and orthogonality of multi-carrier OFDM have been described. Also, presented a mathematical expression to model the OFDM transmitter using linear and nonlinear RF power amplifier to analyze the best performance of the system with different modulations. The simulation results demonstratedthe BER performance of the multi-cattier OFDM transmitter system with and without power amplifiers.

Keywords: *Multi-carrier OFDM, PAPR, Cyclic Prefix, BER Performance.*

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I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a special form of frequency division multiplexing (FDM) with excellent qualities of sub-channels orthogonality. It is a technique that simply combines modulation and multiple access to split a wideband channel into narrowband channels. This offers an opportunity to a user in sharing channel resources with other users through the ability of the technique to multiplex large amount of signal and enhance throughput in the system. It is an efficient multicarrier mapping system that is able to implement high data rate to meet the ultimate demand of massive growth and emergence of future technologies in the mobile communication industry. However, for this reason, several wireless communication systems such as Long Term Evolution (LTE) [1-3], Long Term Evolution Advanced (LTE-A) [1, 2], World Interoperability for Microwave Access (Wi-MAX) [2, 4], Wireless Fidelity (Wi-Fi) [5-7], Wireless-LAN and beyond [8], Digital Audio Broadcast (DAB) [9], Digital Video Broadcast (DVB) [10], Third Generation (3G) [11, 12], Fourth Generation (4G) [12], Fifth Generation (5G) [3, 13], Cognitive Radio Networks (CRNs) [14, 15], Spatial Modulation [16] and other future technologies adopt OFDM system.

One of the significant motives for using orthogonal frequency division multiplexing technique in the transceiver device is to improve system robustness and transmission speed. Robust system mitigates narrow band channel interference and frequency selective channel interference. The vulnerability of narrowband carrier is that a weak interference in the channel can results to complete system failure. The multicarrier multiplexing system resist the effect of interference which affects only few subcarriers. However, this means the multicarrier system will not experience complete link failure due to interference. The effect of interference has impact only on certain potion of the subcarriers. Orthogonal frequency division multiplexing provides reliability and spectral efficiency. It also protects systems against inter-carrier interference (ICI) and inter-symbol interference (ISI). In OFDM system, inter-symbol interference increases when delay spread (τ_d) in the channel is larger than the symbol duration (T_s). The larger the channel delay spread, the severe the inter-symbol interference. However, at the same time, the longer the symbol duration over channel delay spread, the more free inter-symbol interference channel is projected. Mobile communication networks such as long termevolution (LTE), LTE-Advanced and World Interoperability for Microwave Access (Wi-MAX) are multipath systems. These systems are designed with long range capability to transmit multiple signals that can be in line of sight and non-line of sight. Due to multipath fading of the signal, the delay spread (τ_d) becomes prominent. Hence, most of these mobile communication networks adopted orthogonal frequency division multiplex scheme, because of it resilience against inter-carrier interference (ICI) and inter-symbol interference (ISI) [17-23].

In section II, the philosophy of OFDM signaling and current state of the art are discussed, proposed mathematical expression is analyzed in section III, proposed OFDM system modeling using linear and nonlinear RF power amplifier with simulation results are presented in section IV, while section V concludes the paper.

II. PHILOSOPHY OF OFDM SIGNALING AND CURRENT STATE-OF-THE-ART

To transmit OFDM signals, free interference, the orthogonality of the carriers must be kept in place. OFDM orthogonality means signals are mutually kept free from each other and are transmitted accurately in a common channel without interference. However, the relationship between all the carriers must be carefully managed. The signals are produced in digital form rather than analogue. Analogue makes it a complex system and difficult to process signal due to large numbers of local oscillators that slow down the system. Therefore, OFDM signals are generally convey in digital form. Figure 1 has presented a typical OFDM transceiver system. In the baseband, the OFDM signals are randomly generated in the frequency domain. The signals are mapped based on mapping scheme (e.g. QPSK, 16-QAM, 64-QAM, 256-QAM, etc.) used in the system. The OFDM signals are transformed from serial-to-parallel (S/P) and using inverse fast Fourier transform process (IFFT) to modulate the signals in time domain. At the receiver, fast Fourier transform process (FFT) is used to demodulate and recover the OFDM transmitted signals. Cyclic prefix is used as a copy of the last portion of the OFDM symbol before the parallel-to-serial transformation, as a copy of the last slot of the OFDM symbol, to prevent the signals from inter symbol interference (ISI). Inter-symbol interference (ISI) occurs due to multipath fading, caused by time diffusion of the channel. However, up to 25% of the cyclic prefix symbol length, being one-quarter (1/4) of the FFT size is required. The IFFT complex time domain signal, having cyclic prefix added is now transferred to digital-to-analogue converter where the real and imaginary symbols of the OFDM is up-converted. AT the carrier frequency channel, in-phase and quadrature (I and Q) signals are produced to band-pass level. These real and imaginary complex signal is transmitted to the digital pre-distortion and power amplifier system which pass through the RF front-end of the OFDM transceiver[17, 24-26].

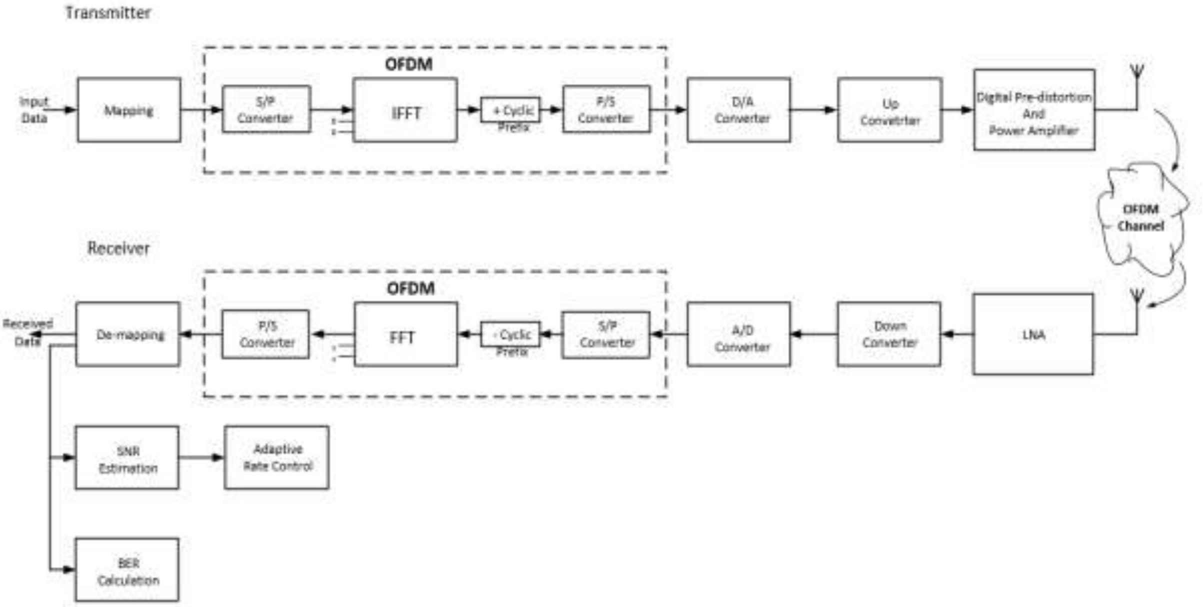


Figure 1: High level multi-carrier OFDM architecture.

The OFDM system in figure1 explains the components that make-up the transmitter and the receiver. This paper describes the most significantcharacteristicsof OFDM systems:

A. Cyclic Prefix

Wireless communication applications are researching for answers against time dispersion effect caused by multi-path effect. Multipath effect is as a result of non-line-of-sight transmission where transmission signal reflects on objects in multipath environment, such as high buildings, mountains, walls, etc. These signals are received at different times due to different transmission paths and distances. These cause channel delay in the propagation environment, spread borders of the symbol and causing energy outflows between the symbols. Cyclic prefix is used in preventing OFDM data stream against inter-symbol interference (ISI). To achieve cyclic prefix in OFDM system, original copy of the data length is copied to the front of the OFDM symbol. To solve the effect of inter-symbol interference, the OFDM channel maximum delay spread must be less or equivalent to the length of the cyclic prefix [27, 28]. The cyclic prefix inclusion in the OFDM symbol affects the linear time invariant between the symbol and the channel impulse response, which is however, transformed to a cyclic convolution [28]. Figure 2 shows the inclusion of cyclic prefix in the symbol.

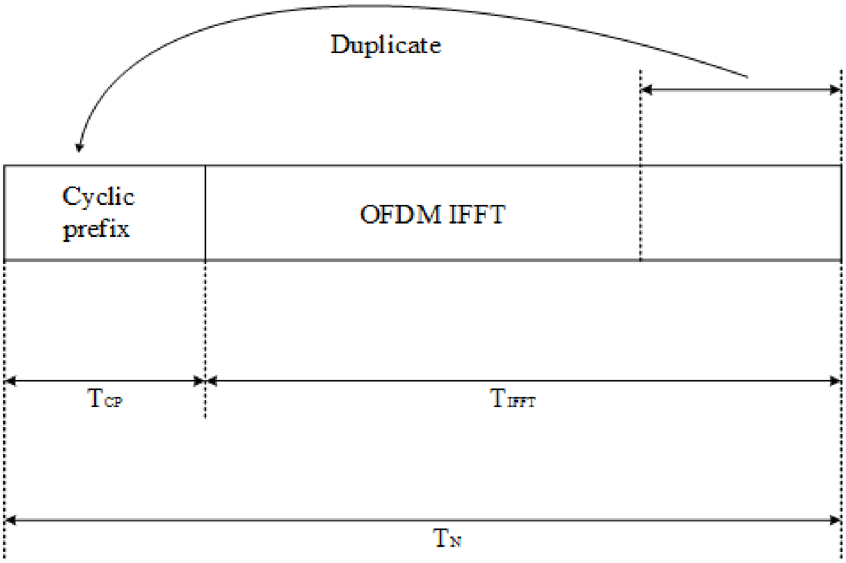


Figure 2: Addition of cyclic prefix to an OFDM signal.

The new length of OFDM symbol after adding cyclic prefix is represented by:

$$T_N = T_{CP} + T_{IFFT} \tag{1}$$

where T_N is the total length of OFDM symbol time, T_{CP} is the length of guard interval in sample time, T_{IFFT} is the useful data duration of IFFT for OFDM signal. Cyclic prefix protects the transmitted OFDM symbol (T_{IFFT}) against inter symbol interference. OFDM data symbols travel on propagation paths are received at different times. The multipath delay spread effect caused by obstacle in propagation environment, influences some of the OFDM symbols to arrive later than others. This effect however, results to inter symbol interference (ISI). The cyclic prefix keep the symbol clean to arrive at the receiver without changes by adding T_{CP} to the transmitted signal [28].

B. Spectral Efficiency

Spectral efficiency is another name for bandwidth efficiency or spectrum efficiency. It refers to the amount of information that is able to be delivered per a given bandwidth in particular communication system. It measures the information symbol in bits/s/Hz. Spectral efficiency determines the performance of a radio communication system. The higher the spectral efficiency, the excellent quality of service can be achieved for the subcarrier system. One of the ways spectral efficiency can decline in OFDM systems is by the used of cyclic prefix [29, 30]. Cyclic prefix is added to each OFDM symbol in the subcarrier for accurate inter symbol interference reduction. Like discussed previously, it was stated that for the cyclic prefix to be active in eliminating the inter symbol interference, the cyclic prefix will have the same length or more than the maximum delay spread of the OFDM channel. However, the spectral efficiency in OFDM system is higher than in FDM system. If m is the number of OFDM carriers, while g is added as cyclic prefix, then the spectral efficiency can be summarized as:

$$\eta = \frac{m}{m+g} \tag{2}$$

For a given OFDM that is band-limited, bandwidth (BW) is frequency spacing between the upper and lower channel index written as:

$$BW = \pm \frac{N_i}{2}\Delta f = \frac{N_i}{2}\Delta f - \left[-\frac{N_i}{2}\Delta f\right] = N_i \Delta f \tag{3}$$

where $\pm\frac{N_i}{2}$ stands for the upper and lower bound of the channel index, while Δf is the frequency spacing in the OFDM channel. The frequency spacing (Δf) can be rewritten as $\frac{1}{T_{IFFT}}$, where T_{IFFT} stands for the useful duration of OFDM symbol [29, 30]. In this case, the spectral efficiency in relation to bits rate per given bandwidth can be expanded in this form as:

$$\eta = \frac{R_b}{BW} = \frac{R_b}{N_i \Delta f} = \frac{R_b}{N_i \times \frac{1}{T_{IFFT}}} = \frac{R_b T_{IFFT}}{N_i} \tag{4}$$

where $N = R_b \times T_{IFFT}$ and R_b is the data bit rate in bits/s. Assuming that the OFDM system adopt a 16-QAM mapping technique to modulate the overall number of bits for N sub-channels involved [29], can be written as:

$$N = N_i \log_2(M) \tag{5}$$

Hence, total number of sub-carriers in OFDM symbol (N_i) can be written as:

$$N_i = \frac{N}{Log_2(M)} = \frac{R_b \times T_{IFFT}}{Log_2(M)} \tag{6}$$

Substituting equation 6 into4 can re-illustrate the spectral efficiency to be written as:

$$\eta = \frac{R_b \times T_{IFFT}}{1} \times \frac{1}{\left[\frac{R_b \times T_{IFFT}}{Log_2(M)}\right]} = \frac{R_b \times T_{IFFT}}{R_b \times T_{IFFT}} \times Log_2(M) = 1 \times Log_2(M) \tag{7}$$

Adding cyclic prefix (T_{cp}) to the OFDM symbol guarantees prevention against inter symbol interference (ISI) and to lengthen the size of the OFDM symbol shown in figure 2 is rewritten as:

$$T_N = T_{CP} + T_{IFFT} \tag{8}$$

where T_N is the overall OFDM symbol time, with added cyclic prefix, while T_{CP} is cyclic prefix which is assume to be slower than the poorest delay spread. To express spectral efficiency in terms of Δf and T_{IFFT}, we can recall equation 4 to give:

$$\eta = \frac{R_b}{N_i \Delta f} = \frac{R_b}{\frac{N}{Log_2(M)} \times \Delta f} = \frac{R_b}{\frac{R_b T_{IFFT}}{Log_2(M)} \times \Delta f} = \frac{Log_2(M)}{T_{IFFT}\,\Delta f} \tag{9}$$

By adding cyclic prefix, the overall OFDM symbol T_N shown in equation 8, can be achieved when substituting T_{IFFT} in equation 9 which is expressed as:

$$\eta = \frac{Log_2(M)}{T_N \Delta f} = \frac{Log_2(M)}{(T_{IFFT} + T_{CP}) \times \Delta f} = \frac{Log_2(M)}{(T_{IFFT} + T_{CP}) \times \frac{1}{T_{IFFT}}} = \frac{Log_2(M)}{1 + \frac{T_{CP}}{T_{IFFT}}} \tag{10}$$

The equation 10 illustrates the spectral efficiency of the overall OFDM symbol time when cyclic prefix is added. However, including the prefix in the OFDM symbol to overcome inter symbol interference has at the same time reduced the spectral efficiency. It is obvious that adopting mapping scheme for the OFDM system depends on the size of the cyclic prefix. Application of more complex mapping scheme like the 16-QAM, 64-QAM, 256-QAM, results to trade-off between the spectral efficiency and channel robustness against delay spread. The higher the mapping scheme the higher the spectral efficiency. The bit-error-rate performance analysis will be poor and there will be reduction in transmit power [30].

C. Orthogonality of Multi-carriers

Orthogonal frequency division multiplex systems are spectrally efficient such that the signals are inherently orthogonal. Signals are mutually independent when they are orthogonal. Orthogonal system allows perfect multi-data transmission over a common carrier, without interference. Absence of orthogonality in a system causes distortion between the information data which can result to loss of communication [31, 32].

OFDM systems achieve orthogonality when set of functions synchronize with each other such that the s^{th} basic function of the transmitter $\psi_s(t)$ match with the r^{th} function of the receiver $\psi_r(t)$. Hence, the set of functional carriers are orthogonal to each other if they equal the conditions in equation 11 which is expressed as:

$$\int_x^y \psi_s(t)\psi_r(t)\,dt = \begin{cases} (y-x) \quad for\ s=r \\ \\ 0 \qquad for\ s\neq r\ \ and\ \ (y-x) = N\Delta t \end{cases} \tag{11}$$

The first case expresses that the two functions are orthogonal by satisfying the condition $\int_x^y \psi_s(t)\psi_r(t)\,dt = 0$. And if the two set of functions lose their orthogonality such that the s^{th} basic functions of the transmitter $\psi_s(t)$ mismatch the r^{th} functions of the receiver $\psi_r(t)$, distortion occurs in the channel and results to inter-channel interference. The OFDM set of transmitted carriers are defined as:

$$\psi_s(t) = e^{j2\pi\left(\omega_o + \frac{n}{N\Delta t}\right)t} \tag{12}$$

where n = 0, 1,, 2, …, N-1. While the OFDM received carriers are defined as:

$$\psi_r(t) = e^{j2\pi\left(\omega_o + \frac{n}{N\Delta t}\right)t} \tag{13}$$

Hence, the two sets of carriers are orthogonal to each other by setting condition expressed as:

$$\int_x^y \psi_s(t)\psi_r(t)\,dt = \int_x^y e^{j2\pi(s-r)\frac{n}{N\Delta t}dt} \tag{14}$$

$$for\, n = s\ or\ r$$

There is a correlation between transmitted or received set of carriers. If s^{th} function matches with r^{th} function. Then, the two sets are orthogonal as expanded in 15 and 16:

$$\int_x^y \psi_s(t)\psi_r(t)\,dt = \frac{e^{j2\pi(s-r)\frac{y}{N\Delta t}} - e^{j2\pi(s-r)\frac{x}{N\Delta t}}}{j2\pi(s-r)/N\Delta t} \tag{15}$$

$$= \frac{e^{j2\pi(s-r)\frac{y}{N\Delta t}}\left(1 - e^{j2\pi(s-r)\frac{x-y}{N\Delta t}}\right)}{j2\pi(s-r)/N\Delta t} \tag{16}$$

Hence,

$$\int_x^y \psi_s(t)\psi_r(t)\,dt = 0 \tag{17}$$

$$for\, s=r\ \ and\ \ (y-x) = N\Delta t$$

Finally, this has shown that every two carriers are orthogonal to each other, until they prove otherwise. Inter-channel interference is no longer existing when two carriers are in orthogonal state [32]. Hence, this can be used in OFDM signal mathematical expression.

III. PROPOSED MATHEMATICAL EXPRESSION

This part of the work presents a mathematical definition of the OFDM system. It is imperative to see how the OFDM signal can be transmitted and received in a transmission system. This allows us to understand the mathematical presentation, operational function of each individual system and the effects of imperfections in the communication channel. The OFDM signal is transmitted in frequency domain with a vast number of sub-carriers, closely spaced to one another. A Fast Fourier Transform (FFT) is used as a modern digital communication and signal processing technique to substitute the large number of space and energy consuming components in the transceiver system.

The OFDM is a multi-carrier structure which each narrowband carrier is modulated side-by-side in parallel with other narrowband carriers [18, 22, 33]. From the above expression which stated that $\{\psi_p(t)\}$ is the OFDM orthogonal signal set. An OFDM signal based on this arrangement can be expressed as:

$$y(t) = \sum_{k=-\infty}^{\infty} \sum_{p=0}^{N-1} x_{k,p}\, \psi_p(t - KT) \tag{18}$$

where $\psi_p(t) = e^{j2\pi f_p t}$ is also expressed as the sub-carrier in the equivalent baseband signal of the OFDM system. $f_p = f_0 + \frac{p}{T}$, f_p is the p^{th} sub-carrier frequency, equally spaced by: $\Delta f = \frac{1}{T}$, $p = 1, 2, 3, ..., N-1$, $0 \le t \le T$. T is the OFDM symbol duration and $x_{k,p}$ is the data transmitted on the p^{th} of the k^{th} symbol. Hence, the signal can be expanded as:

$$y(t) = \sum_{k=-\infty}^{\infty} \sum_{p=0}^{N-1} \{u_{k,p} \cos(2\pi f_p (t - KT)) - v_{k,p} \sin(2\pi f_p (t - KT))\} \tag{19}$$

The OFDM symbol is represented as:

$$y(t) = \sum_{p=0}^{N-1} u_p \cos(2\pi f_p t) - v_p \sin(2\pi f_p t) \tag{20}$$

k is assume to be 0, while u_p is the p^{th} complex baseband symbol of the frequency domain. However, for multi-carrier equivalent using Inverse Discrete Fourier Transform where a single carrier of the OFDM signal can be expressed as:

$$S_c(t) = Z_c(t) e^{j|2\pi f_c t + \varphi_c(t)|} \tag{21}$$

In the OFDM signal, there are number of *N* carriers, Z_c is the amplitude, while φ is the phase of the single carrier. The total OFDM complex signal can described as:

$$S_s(t) = \frac{1}{N} \sum_{p=0}^{N-1} Z_p(t) e^{j|2\pi f_p t + \varphi_p(t)|} \tag{22}$$

where $f_p = f_i + p\Delta f$.

$Z_p(t), \varphi_p(t)$ and f_p represent amplitude, phase and carrier frequency of the p^{th} carrier. The OFDM complex waveform is a continuous signal. If the waveform of each component of the signal is taken into account over one period of OFDM symbol, the signal sampled at the sampling frequency $\left[\frac{1}{\Delta t}\right]$, $Z_p(t)$ and $\varphi_p(t)$ come to be Z_p and φ_p .

$$S_s(k\Delta t) = \frac{1}{N} \sum_{p=0}^{N-1} Z_p e^{j|2\pi(f_i + p\Delta f)k\Delta t + \varphi_p|} \tag{23}$$

Hence, the sampled signal can be described as:

$$S_s(k\Delta t) = \frac{1}{N} \sum_{p=0}^{N-1} \left| Z_p e^{j|2\pi(f_i k\Delta f) + \varphi_p|} \right| . e^{j2\pi pk\Delta f\Delta t} \tag{24}$$

At this point, the signal has been sampled to N samples by means of sampling frequency $\left[\frac{1}{\Delta t}\right]$. It is worthy to take into account how much time is required to analyze the signal to a specific number of N samples. If we now assume $f_i = 0$, equation 24 can be simplified and the signal is given as:

$$S_s(k\Delta t)=\frac{1}{N}\sum_{p=0}^{N-1}\left|Z_p e^{j\varphi_p}\right|.\left|e^{j2\pi pk\Delta f\Delta t}\right| \qquad (25)$$

If equation 25 is now compared with the form of Inverse Fourier Transform (IFT) which can be described as the:

$$g(k\Delta t)=\frac{1}{N}\sum_{p=0}^{N-1}G\left|p\Delta f\right|e^{j2\pi pk/N} \qquad (26)$$

The functions $(Z_p, e^j \; and \; \varphi_p)$ in equation25 is the sampled signal representation of signal in frequency domain. While, $S_s(k\Delta t)$ is the time domain signal representation. Hence, time and frequency domain are the same if the condition is satisfied when:

$$\Delta f=\frac{1}{N\Delta t}=\frac{\Delta f}{2\pi} \qquad (27)$$

where the OFDM signal consists of $S_s(k\Delta t)$ as the time domain signal, $Z_p e^{j\left|2\pi(f_i k\Delta f)+\varphi_p\right|}$ is the frequency domain signal, $N\Delta t$ is the symbol duration in each sub-channel and Δf is the spacing in each sub-channel, respectively. It has proven that Inverse Discrete Fourier Transform can generate OFDM signal. Therefore, the OFDM signal can be described by Fourier Transform.

IV. PROPOSED OFDM SYSTEM MODELING USING LINEAR AND NONLINEAR RF POWER AMPLIFIER AND SIMULATION RESULTS

A modelis used to simulate an OFDM signal transmission over a linear and nonlinear RF power amplifiers to determine performance effect of each level of transmission in the systems. The linear system represents the proposed balanced RF power amplifier [34, 35]and the nonlinear system represents class F RF power amplifier[36, 37] respectively. In the model, the OFDM transceiver system is furnished with functional devices and characteristics in different stages to sharpen the baseband signal. These include 128 number of OFDM subcarriers, a 25% cyclic prefix is used in the OFDM blocks to prevent inter symbol interference due to channel delay in the multipath transmission. A fast fading channel is used at 2.655 GHz carrier frequency with over 4 x 10^4 symbols at 20 KHz sampling frequency. The OFDM subcarrier data was generated from the baseband and forwarded to the 16-QAM modulation scheme where the serial data stream was mapped into binary form. The data was reshaped through the serial to parallel conversion. The IFFT was added to convert the subcarrier data from frequency domain to a corresponding discrete samples in time domain. The data was converted back to serial after adding the prefix. The data passed through the RF power amplifier after the analogue to digital conversion. The level of signal distortion is based on the amplifier added to the OFDM system. Generated AWGN and noise was added to the channel as illustrated in figure 1.

At the OFDM receiver side, signal was received by the low noise amplifier before down conversion and analogue-digital signal conversion. The signal was reshaped through serial to parallel conversion, cyclic prefix was removed, and FFT was perform to generate frequency domain OFDM waveforms. To perform channel equalization and reshaping of the signal, parallel to serial conversion was performed. The data stream was mapped using 16-QAM and BER was computed for various systems of amplification.

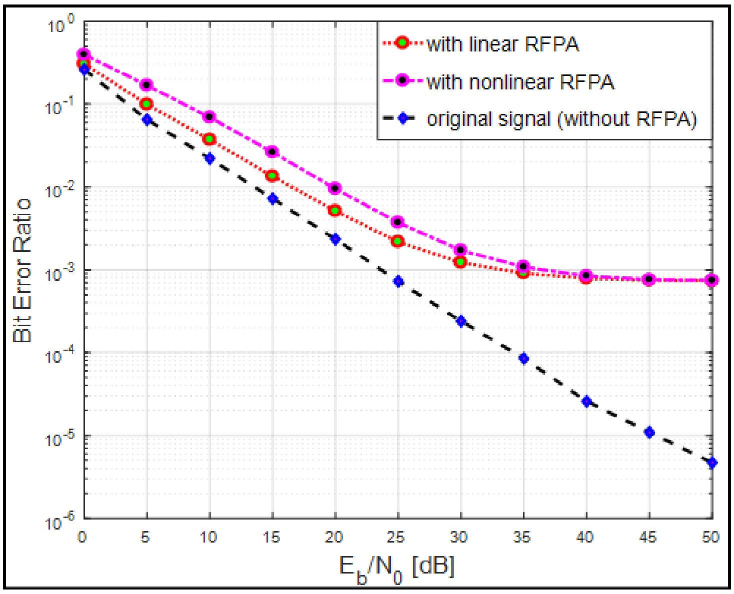


Figure 3: BER performance of the OFDM transceiver.

Figure 3 has shown BER performance of the OFDM transceiver system using linear and nonlinear RF power amplifiers. It can be seen that various system for amplification plays an important role on BER performance of the OFDM transceiver system. Hence, in designing the OFDM system, a RF front end and the acceptable level of distortion, otherwise linearization is required to give adequate recovery at the receiver. The figure has also shown the BER performance versus energy per bit to noise density of the OFDM original signal, then with linear amplifier and with nonlinear amplifier respectively. The result have demonstrated various scenario where the systems do not perform similarly. It can be seen that the OFDM system out performed better than with the RF power amplifier. However, in the case of RFPAs, the linear RF power amplifier is slightly better at the beginning in terms of BER performance. While increasing the energy per bit to noise density, the nonlinear RF power amplifier continued to bridge the gap. We can presume that both linear and nonlinear RFPAs were affected by distortion. In this effect, a pre-distorter is required to linearize the nonlinear behavior of RF power amplifier. The OFDM system is also simulated and analysed with different M-ary modulation techniqes such as QPSK, 16-QAM, 64-QAM and 128-QAM. The BER performance result of the different modulations is shown in Figure 4.

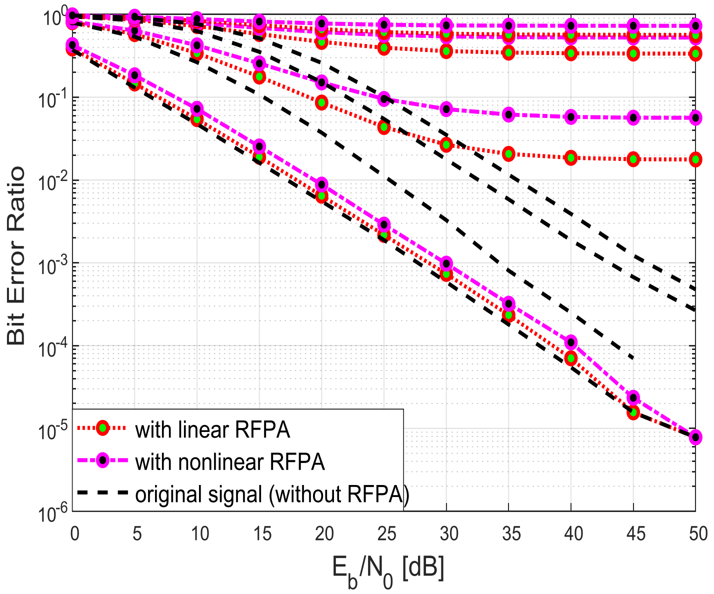
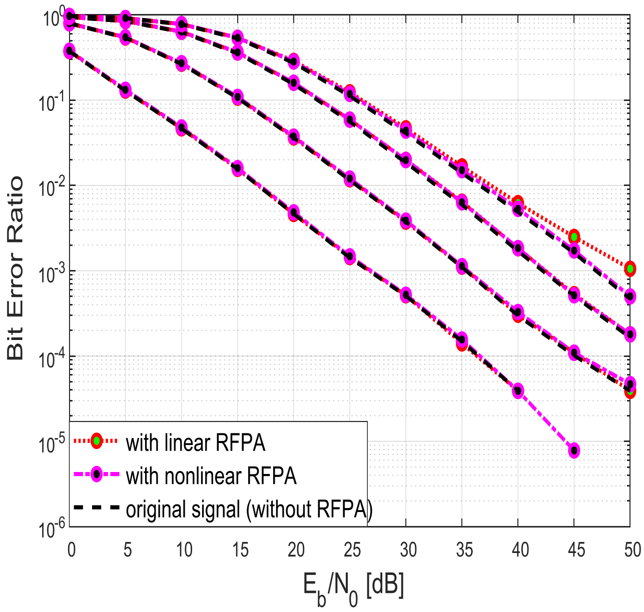
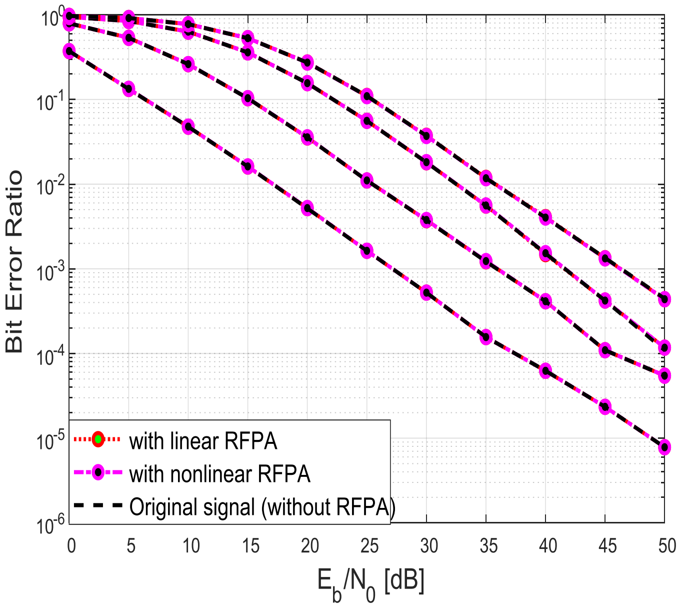


Figure 4: BER performance of the OFDM transceiver with QPSK, 16-QAM, 64-QAM and 128-QAM.

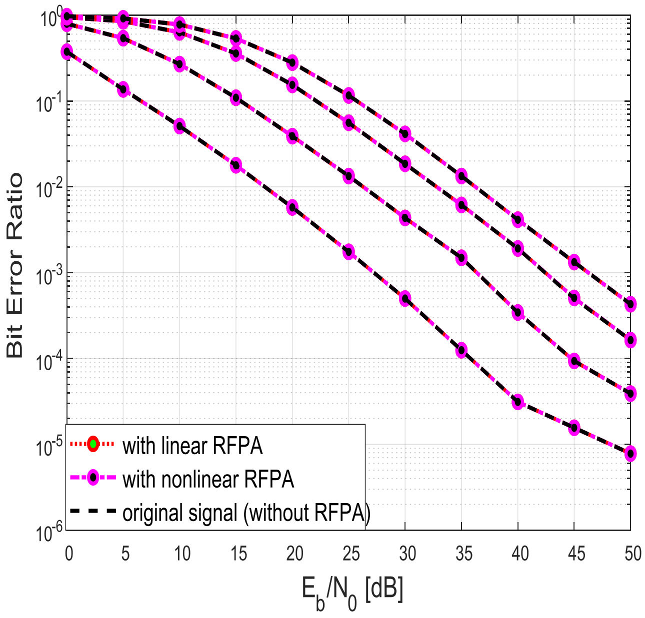
It can be noticed from the figure above that the same scenario has been used which is the OFDM original signal, without and with (linear/nonlinear) power amplifiers. It is also noticed that the lower the modulation, the lower the SNR and the better performance is achieved. The best performance was achieved by QPSK which is the first scenario in the figure. It can be seen that the SNR $\leq$ 40 dB in 2.2 x 10^{-4} BER. However the normal saturation level 1 was maintained for the simulation. Increases inthe distance reduces the strength signals and affect SNR. In this case, the modulation level changes from QPSK level to a more higher level modulation, i.e. 16-QAM, 64-QAM or 128-QAM.



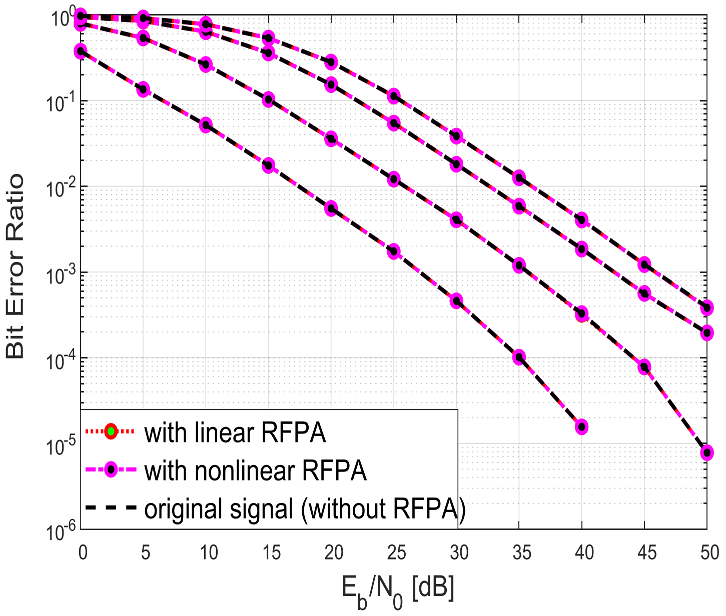
(a)



(b)



(c)



(d)

Figure 5: BER performance of the OFDM transceiver using QPSK, 16-QAM, 64-QAM and 128-QAM. (a) In saturation level 2. (b) In saturation level 3. (c) In saturation level 4. (d) In saturation level 5.

This work also compare the performance of different OFDM modulation schemes in terms BER. Similarly the OFDM system was simulated with different level of saturation as shown in Figure 5. The figure prior to this has shown the BER performance of different modulation techniques with a single saturation level. In this case saturation level is increased to 2, 3, 4 and 5dBm as illustrated in figure 5 (a), (b), (c) and (d). It is clearly seen that increasing the level of saturation sharpen the signal to significant accuracy. That is to say the more saturation in the OFDM system, the more signal pass through high power amplifier with insignificant or no distortion. In addition, this results to better BER performance which also boost the system efficiency. Likewise, decreasing the saturation level appreciate the probability of signal amplitude distortion resulting to poor BER performance. However, the simulation was maintained using the proposed linear balanced power amplifier and the nonlinear class F power amplifier. The simulation results confirm that using saturation level 5 yield a better performance when compared to lower saturation level.

V. CONCLUSION

Orthogonal Frequency Division Multiplexing system (OFDM) has been described in this work. OFDM features, functionality, advantages and disadvantages, the effect of PAPR and reduction techniques were highlighted. This also highlights the influence and importance of high data rate in the communication system. In addition, the effect and avoidance of ISI in the channel have been discussed. The application of IFFT and FFT technology provide effective modulation and demodulation for easy implementation of OFDM in a transceiver system. OFDM has been establish to be appropriate multicarrier modulation technique to avert multipath distortions and robust in multicarrier signaling. OFDM was tested using linear and nonlinear RF power amplifiers over different digital modulation systems. The results show that due to RFPA distortion in the RF front end, the modulation schemes deteriorate in terms of BER. The OFDM signaling performance was affected significantly. ICI reduces the performance of an OFDM system. It can be concluded that the BER for BPSK is less for low SNR compared to that achieved by QPSK and 16-QAM modulations. This simply confirms that OFDM using BPSK is suitable for lower capacity and low power systems, whereas higher modulation schemes are suitable for high capacity and higher power systems.

ACKNOWLEDGEMENTS

An acknowledgement section may be presented after the conclusion, if desired.

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