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Impact of an Radio Frequency[RF]on communication system performance using OFDM

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Abstract

This study examines the techniques of radio frequency modulation and compensation in the context of orthogonal frequency division multiplexing (OFDM). The document details the implementation of various methods designed to mitigate disturbances, including amplitude and phase noise. The RF power amplifier (RFPA) emerges as a vital component in the configuration of radio devices for wireless communication, as it greatly enhances transmitter efficiency. Notably, this power amplifier is one of the most energy-consuming parts; for example, the lifespan of a cell phone battery is heavily reliant on the PA's power efficiency. Additionally, there is a significant need to ensure the transmission of data at the maximum possible rate for the allocated channel bandwidth, thereby promoting high spectral efficiency.

.Keywords— Radio attenuation, radio frequency interference in communication systems, OFDM filter in wireless transceivers, BER error rate, noise, math lab, Simulink

1.Introduction

In industrial applications, it is essential to focus on the generation of high-quality radio frequencies and energy efficiency. Linearity refers to the amplifier's capability to uniformly amplify all components of a signal, ensuring that each part is enhanced equally, which is a significant advantage in power amplifiers (PAs). It is crucial to establish protected areas to minimize overlap and manage spectrum growth. Typically, power amplifiers are not adequately documented, which leads to distortion and a lack of linearity in radio transmission devices. To enhance energy efficiency, amplifiers should operate as close to their optimal performance point as possible, while also improving spectral purity in that vicinity. In this regard, the design of the amplifier is vital for creating high-performance energy infrastructure systems for contemporary wireless networks. Moreover, behavioral modeling of protected areas is necessary to evaluate performance and simulate the transmission system effectively, offering a more time-efficient alternative to traditional model-based approaches. [3].

2. Orthogonal Frequency-Division Multiplexing (OFDM).

The transmission technique known as Orthogonal Frequency Division Multiplexing (OFDM) relies on segmenting the channel into multiple narrow sub-channels, each of which is altered using a digital modulation scheme. By transmitting a significant number of closely spaced and interconnected sub-channels simultaneously, OFDM enhances spectral efficiency and increases data transfer rates, which are among its key advantages. Additionally, this technology effectively mitigates the impact of selective frequency fading caused by multipath propagation by ensuring that each sub-channel possesses an adequate frequency range, allowing for a flat fading response when the relationship between the bandwidth and delay length is appropriately managed. Maintaining orthogonality is essential in OFDM systems to prevent interference among sub-channels. This technology offers a robust solution for utilizing the frequency spectrum, although it can lead to reduced spectral efficiency over long distances, necessitating strategies to address this issue [4],

3. The design of modern wireless transmission and reception devices.

The evolution of wireless transmission and reception devices has seen significant advancements over the years. In the development of these devices, three critical factors must be considered: high performance, cost-effectiveness, and the capability to meet the demands of sophisticated wireless communication systems. Figure 1 illustrates the overall architecture of the wireless transmission and reception device, which incorporates multiple antennas on both the transmitting and receiving ends. In contemporary reception systems, signal processing predominantly occurs in the baseband using integrated circuits and compact systems. At the primary range output, the signal is converted to the RF frequency (RF) using either the heterodyne mixing method or direct conversion. The vehicle generates the carrier signal essential for this procedure. Power amplifiers significantly enhance system performance by boosting the signal before it is transmitted. Following this, the front end of the RF FRONT-END system directs the signal to the transmission antennas. The signal received through the wireless channel must undergo processing[5], Generating a wireless radio frequency (RF) signal utilizing low noise amplifiers (LNAs). The frequency is adjusted and converted to a lower range to minimize the signal's frequency spectrum. The signals are then transferred to the baseband for additional processing. The signal processing on the transmission side resembles the digital signal processing that occurs prior to the wireless transmission through the RF front-end interface.

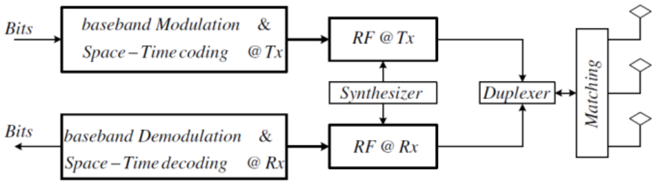


Fig. 1 Design of modern wireless transceivers

Enhanced productivity results from a combination of alterations in data packet transmission techniques and the utilization of advanced radio technologies that necessitate high performance from RF devices. Multiple RF channels can be established with integrated independent transport and a common local oscillator (LO) paired with a separate front unit. Figure 2 depicts the primary components of the IEEE 802.11n wireless LAN. [6].

4/ The phase and capacity noise,

An oscillator is a system designed to produce a periodic signal at a defined or regulated frequency. When it comes to eliminating noise in a radio frequency oscillator (RF), two primary types are encountered: capacity noise and phase noise. The output voltage of an oscillator can be expressed as follows: [6]:

$$V_{out}(t) = (A_o + a_N(t)).\mathrm{Cos}(2\pi f_o t + \varphi_N(t)) \ldots\ldots..1$$

$$V_{out}(t) = A(t).\mathrm{Cos}(2\pi f_o t + \varphi_N(t)) \ldots\ldots..2$$

The average legend of the output signal is represented by FO, which denotes the nominal frequency of oscillation. The variables (T) and ϕN (T) correspond to the fluctuating components of capacity and phase, respectively. These elements contribute to noise, and an ideal becusean oscillator would maintain a constant amplitude (ao) and phase, while the stage would fluctuate at a frequency of 2πFo. The impact of phase and capacity noise on OFDM systems necessitates a performance analysis of the communication system affected by these stages, as well as the influence of capacity noise on RF local oscillators in an AWGN environment. Consequently, it is crucial to assess the acceptable levels of phase and amplitude noise in the local oscillator to ensure optimal system performance and to design the oscillator with constrained maximum phase and amplitude noise. The Bit Error Rate (BER) formula for performance analysis can be derived from the Signal-to-Noise Ratio (SNR) that includes phase and amplitude noise, as opposed to the SNR that excludes these factors.

$$P_{bc}=\frac{2}{K}\left(1-\frac{1}{\sqrt{M}}\right)Q\left(\sqrt{\frac{3K}{(M-1)}}\cdot\frac{E_o}{N_o}\right)\text{......................}3$$

$$Q(x)=\frac{1}{2}\,erfc\left(\frac{x}{\sqrt{2}}\right)\text{..................}4$$

Where $SNR_{with(\phi,A)}$ is the SNR with phase and amplitude noise in the OFDM system.

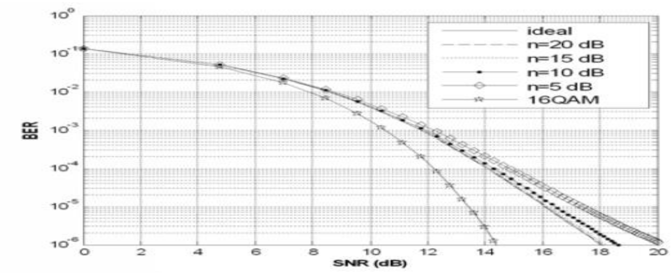


Fig. (2) OFDM system with amplitude and phase noise []

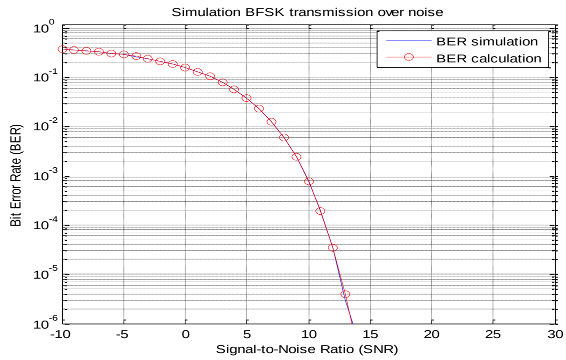


Fig (3). Simulation BFSK transmission over noise

The approximation holds true for a diverse array of RF devices, including amplifiers and mixers. It is crucial to highlight that even-order distortion (n even) is allocated to frequency bands that are significantly distant from the original OFDM signal passband. It is presumed that these components are effectively filtered out and do not affect the Bit Error Rate (BER). Consequently, only odd-order distortion is considered significant. For simplicity, we can disregard the DC term, ao, and represent the output of the nonlinear circuit as follows:

$V_{out}(t) = a_1 v_{in}(t) + a_3 v^3_{in}(t) + a_5 v^5_{in}(t)$……………..5

Where a_1, a_3 and a_5 are the linear gain, third-order and fifth-order nonlinearity coefficients, respectively, while v_{in} is the input OFDM voltage.

$$a_1 = 10^{\frac{G_0}{20}} \quad \text{.......................................6}$$

$$a_3 = -\frac{2}{3} 10^{\frac{3G_0}{20} - \frac{OIP_3}{10}} \quad \text{..............................7}$$

$$a_5 = \frac{8a_1(1-10^{0.05}) - 6a_3\alpha 10^{0.05}}{5\alpha^2 10^{0.05}} \quad \text{......................8}$$

$$\alpha = 2 \times 10^{\frac{P+1-G}{10}} \quad \text{……………………………………..9}$$

5 / Implementing and Simulating RF Receiver with Duplex Filter

Figure 3 illustrates the block diagram of a full duplex transceiver in Matlab Simulink, which includes components such as the transmitter (Tx), receiver (Rx), filters, a white noise source, and additional elements as depicted in the figure.

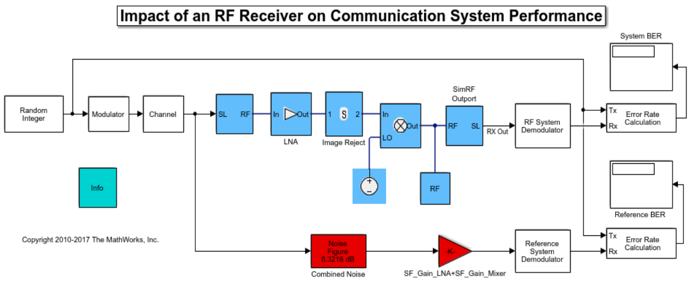


Fig. 4.The impact of an RF Receiver in Math-LAB environment

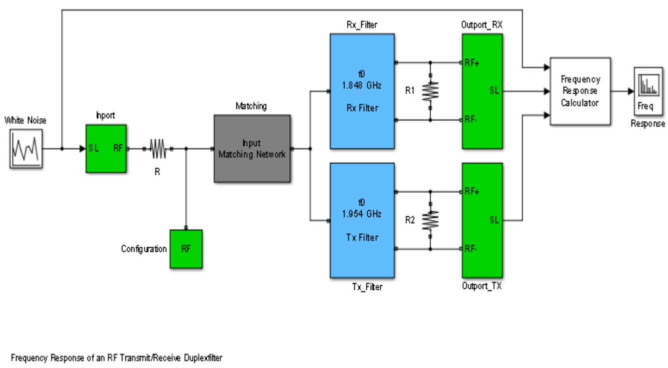


Fig. 5. RF Receiver Duplex Filter in Math-LAB environment

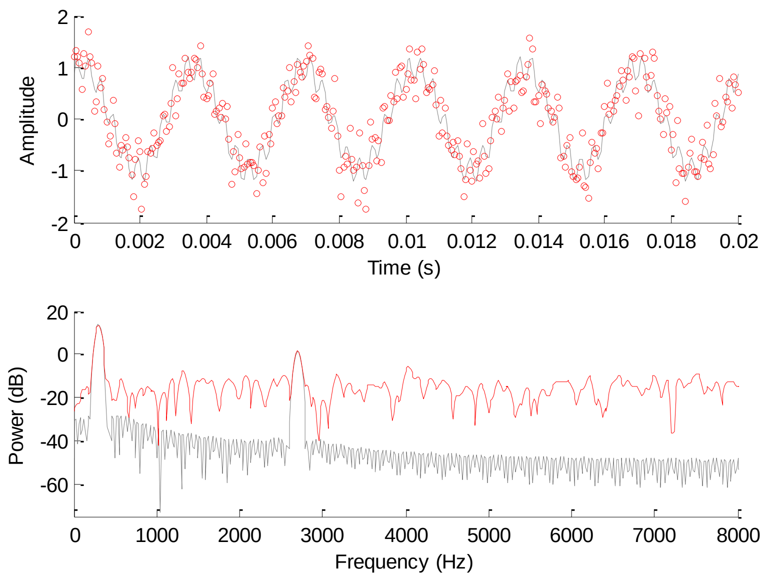
Every signal is affected by noise, which negatively impacts the performance of the system. The level of noise in a signal is typically expressed through the signal-to-noise ratio, defined as SNR = S / N, where S represents the power of the signal and N denotes the power of the noise. This ratio is often dependent on frequency. The decrease in SNR across a two-port network is described by the noise factor

$$F = \frac{SNR_I}{SNR_O} \qquad \text{.................10}$$

where SNR_I and SNR_o are the input and output signal-to-noise ratios respectively.

```
%* Bit Error Rate (BER) calulation *********%
  [err, rate]= symerr([x_inp_I;x_inp_Q], [x_out_I;x_out_Q]);
Rate(dB)= Rate(dB) + rate;
.
.
.
BER_th=(1/2)*erfc(sqrt(SNR/2)); % theoritical calculation for BER
```

When **SNRdB=-10:30; in dB and SNR=10.^(SNRdB./10);**



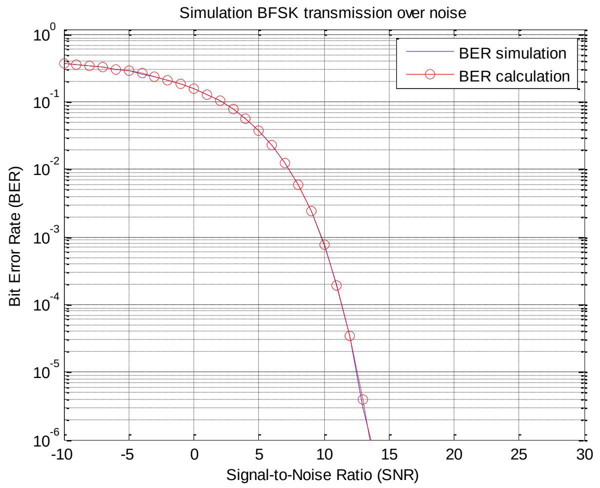


Fig 6. Simulation BER of BFSK transmission over noise

6 / Simulation Result.

To initiate the process, execute the command open system('RF') in the Simulink Command Window. Then, choose the Simulation Run option. The vector Scope will present the envelope voltage transfer functions for both filters. Duplexing can be observed in the frequency response of these filters. The frequency values displayed on the X-axis correspond to the RF carrier. To determine the absolute frequencies, simply add the value of the Carrier frequencies parameter from the In port block to the frequencies illustrated in the figure. (7).

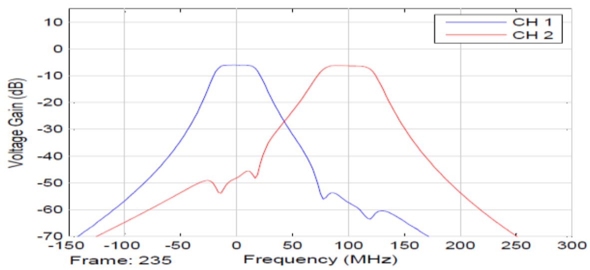


Fig. 7. Calculating a Transfer Function Using a White Noise Source

As illustrated in Figure (8) c, the improvements are evident. The solid line represents the measurement results for the new configuration. Our findings indicate that the simulation aligns closely with the measurement outcomes. While our primary focus has been on enhancing isolation methods, Figures (8) a and b reveal that the passband performance has also seen enhancements. This underscores the effectiveness of our proposed methodology

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and the innovative concepts introduced here. However, discrepancies between the simulation and measurement results persist, which may be attributed to the modeling assumptions.

```
snr = 8; %desired SNR level (dB)
fs = 16000;   % sampling frequency (Hz)
Ts = 1/fs;    % sampling period (s)
duration = 20; % signal duration (ms)
time = [ 0:Ts:duration*1E-3 ];%time vector (s)
N = length( time ); % signal length (samples)
nfft = 2^nextpow2( 2*N );%FFT analysis length
freq = [ 0:nfft-1 ]/nfft*fs;%frequency vector
(Hz)
```

The duplexer's complex structure necessitates that we model the package, die, and bonding wires separately, after which we combine these models to obtain the overall response. The couplings between these components are not considered. Despite these modeling assumptions, Figure 8 displays a comparison of the simulation results with the measured outcomes for the new duplexer, indicating that the results are sufficiently reliable for the analysis and design of the duplexer package..

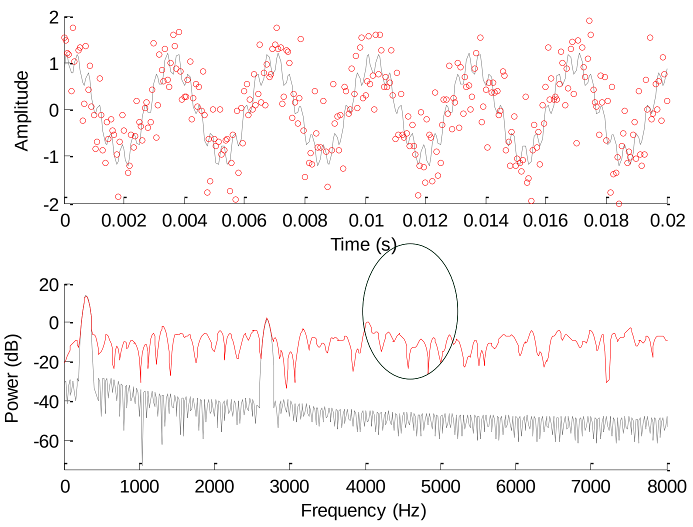


Fig. 8. (a) Frequency response in the Rx channel

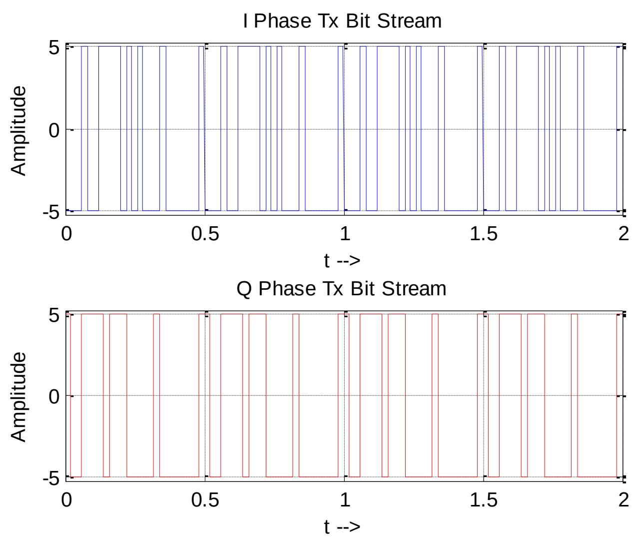
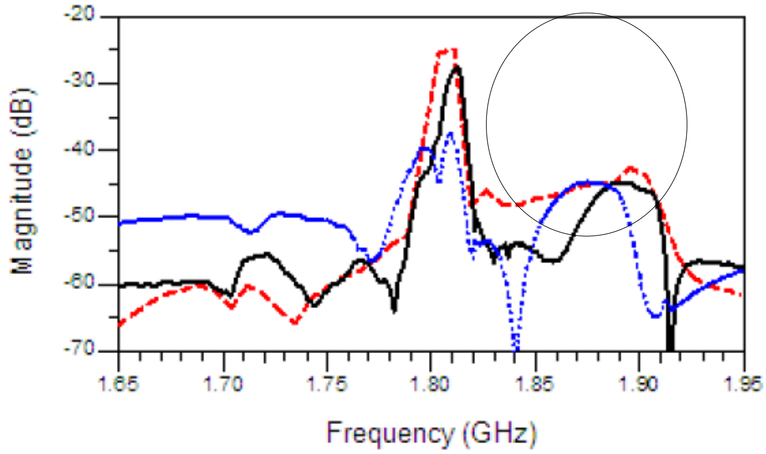


Fig. 8. (b) Frequency response in the Tx channel.



(c) Isolation between the Tx and Rx channels**.**

Fig. 8.a.b.c Comparison of the simulation and measurement

results for new duplexercompared with Ex. Studies..

7/ Conclusion

This research paper introduces an optimization strategy aimed at enhancing transmission range isolation, achieving an improvement from -20 dB to -40 dB. This advancement plays a crucial role in reducing circular degradation and minimizing phase noise in Orthogonal Frequency Division Multiplexing (OFDM) systems. The key findings are as follows: - System Performance Evaluation: The performance of the system is assessed by determining the Bit Error Rate (BER) in relation to the Signal-to-Noise Ratio (SNR), taking into account the impacts of phase noise and nonlinearity. - Nonlinear Amplification: An analysis of nonlinear amplification in power amplifiers and random fluctuations in local oscillators is conducted using a specialized simulation model that omits third-order memory effects for enhanced accuracy. - Multilinear Transfer Model: A multilinear transfer model is created to evaluate nonlinear distortions and prevent third-order memory effects, thereby ensuring more precise assessments. - Improvement in Passband Performance: In addition to enhancing transmission range isolation, a notable improvement in passband performance has been recorded. In conclusion, this research offers a thorough approach to enhancing transmission range isolation while preserving the overall performance of the system.

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