

In-Phase and Quadrature Imbalance Compensation by Using Direct Conversion Transmitters

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ABSTRACT: While transmitting the data over communication channel, various problems such as communication error and mismatch arises. For reducing those errors, frequency selective I/Q imbalance using Direct Conversion transmitters can be implemented. I/Q imbalance compensation procedure has been derived and incoherent measurements are required for avoiding the need for time, frequency and phase synchronization between the transmitter and the RF measurement unit. By using I/Q imbalance the Bit Error Rate and Throughput value will be improved because of that Efficiency will be low and long data transmission will be occurred. To overcome this I/Q imbalance, signal injection method will be used. In signal injection extra default signal is added in that phase and gain will be compared because of that the mismatch occurred here will be reduced. This architecture presents a good balance between different design aspects and enables to minimize the sampling frequency of the Digital-to-Analog (DAC) and Analog-to-Digital (ADC) Converters.

KEYWORDS: IQ Mismatch, Broad band signal, Signal feed through scheme, Design methodology.

I.INTRODUCTION

Recently, the increasing request for broadband mobile connections has lead to the development of advanced radio communication standards and interfaces, with more tight requirements about specifications of transmitter (TX) and receiver (RX) devices. The most effective analog TX scheme is the direct conversion architecture that is sketched in Figure.1. Using only simple analog stages, this architecture is able to directly translate in-phase (I) and quadrature (Q) components of the complex baseband signal to RF [1]. The main disadvantage of this simple scheme is that, due to analog components, many additional impairments, caused by thermal and electronic noise, phase noise, DC-offset, signal cross-talk, local Oscillator (LO) leakage, non-linearity, and I/Q imbalance, appear on the output [2]. I/Q imbalance impairments are due to the mismatched frequency response of the I and Q processing chains and/or the lack of orthogonality between these I and Q paths that causes frequencydependent distortions.

The most apparent effect of I/Q imbalance problem is the introduction of signal self-mixing [2]. If compared to traditional heterodyne or super-heterodyne schemes, that do not suffer from self- mixing effects, I/Q imbalance can cause serious performance degradation in direct-conversion architectures especially for wideband, high-rate, and high-order modulation applications such as those found in advanced WLAN and 3.5G/4G systems. In these cases, it is common practice to measure the RF signal with an additional reference receiver and to introduce digital compensation stages in the transmitter. The auxiliary receiver chain may be implemented by exploiting both on-line or off-line schemes according to the presence, or absence, of suitable circuitry for real-time monitoring of the received signal, respectively.

The I/Q imbalance problem has been extensively studied in the literature: some algorithms compensate for narrowband signals [3]–[5] while others implement wideband signal compensation techniques. As far as transmitter devices are concerned, some I/Q compensation algorithms rely on blind methods, decorrelation and adaptive filtering techniques, and a priori knowledge about the signal waveform statistical behavior such as WSS Gaussian assumption,

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signal circularity or signal properness features. Other TX compensation techniques depend on availability of known simple baseband signals, multiple test signals such as OFDM pilot tones or demodulated signal samples.

II. RELATED WORK

The performance of the transceiver architectures can be seriously deteriorated by the phenomenon called I/Q imbalance. I/Q imbalance stems from relative amplitude and phase mismatch between I- and Q-branches of the transceiver. So that self-interference or adjacent channels interference is introduced. Analysis of the real-time prototype implementation of the transceiver unit realizing widely-linear least-squares based I/Q imbalance estimation algorithm and corresponding pre-distortion structure proposed earlier by the authors [1]

OFDM(orthogonal frequency-division multiplexing) is one of the key digital communication technologies of the current decade. The first part of this paper presents the fundamentals of OFDM and its benefits in the presence of multipath propagation in a tutorial-like fashion. The second part details on some of the most important aspects of OFDM transceiver implementation: concept of receiver channel filtering and A/D conversion, radio impairment compensation (I/Q mismatch), and OFDM demodulator (FFT) design [2]. Impact of parameters on the estimation performance is investigated and it is consistent with our analysis. After CFO correction, a blind based I/Q imbalance estimation and compensation algorithm is applied. The final detection performance demonstrates that the virtual carrier based CFO estimation performance is good enough for subsequent I/Q imbalance estimation and compensation. [3]

A flexible Space-time coding system with unequal error protection. Multiple transmit and receive antennas and bit-interleaved coded modulation techniques are used combined with rate compatible punctured convolution codes. A near optimum iterative receiver is employed with a multiple-in multiple-out inverse mapper and a MAP decoder as component decoders. [4].

III. PROBLEM STATEMENT

The most effective analog TX scheme is the direct conversion architecture designed in existing. Using only simple analog stages, this architecture is able to directly translate in-phase (I) and quadrature (Q) components of the Complex baseband signal to RF. In this way, it is possible to decouple the design of RFICs from Base Band (BBIC) ones. The main disadvantage of this simple scheme is that, due to analog components, many additional impairments, caused by thermal and electronic noise, phase noise, DC-offset, signal cross-talk, Local Oscillator (LO) leakage, non-linearity, and I/Q imbalance, appear on the output as described.

IV. EXISTING SYSTEM

As sketched in Figure.1, a generic direct-conversion transmitter is composed by many analog blocks, which are built with discrete or integrated analog components. Due to component tolerance and aging, variable operating conditions, circuit topology, interferences, and noise effects, the actual transfer function of the analog blocks is only an approximation of the ideal one and the transmitted RF signal is distorted causing performance degradation. These impairments may be divided into linear (i.e., I/Q imbalance, I/Q or DC offset, thermal noise) and non-linear (i.e., power amplifier non linearity and phase noise) ones. Figure.1 does not explicitly show DC-offset terms: these effects are supposed to be compensated by an appropriate DC-offset calibration scheme.

In the next sections, pass band signals will be indicated with the tilde mark, the subscript I (or Q) will be used for the in-phase or quadrature terms of the baseband complex signals while the subscript r (or i) will indicate the real (or imaginary) part of the complex filters, respectively. The I/Q imbalance due to a mismatch between the I and Q branches will be described assuming one branch as ideal (e.g., I) and assigning all relative mismatch to the other one (e.g., Q).

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V.PROPOSED SYSTEM

The aim of this paper is to propose a compensation strategy that is able to easily identify the model of the In-phase/ Quadrature (I/Q) impairments of Radio-Frequency (RF) direct-conversion devices and to efficiently compensate these unwanted effects. In fact, direct-conversion transmitters that integrate analog and digital components introduce a wideband frequency-dependent I/Q mismatch that strongly reduces the up-converter performances. The wider the signal bandwidth or the higher its spectral efficiency, the more severe the I/Q artifacts on the up-converted signal become.

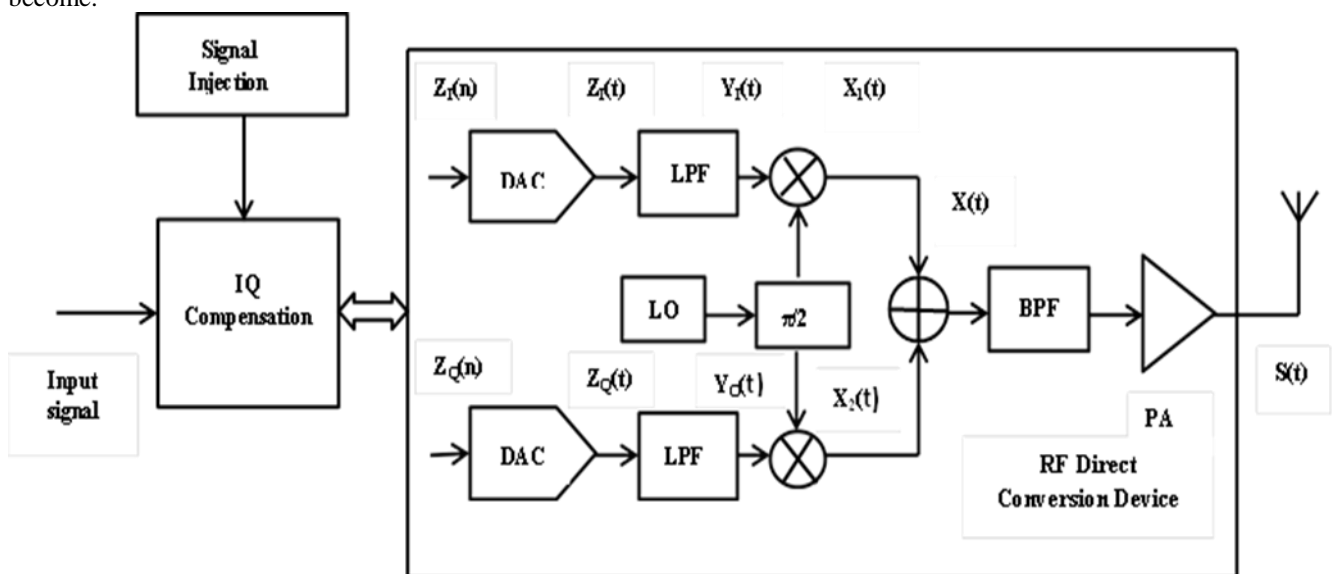


Figure.1: Proposed Design with signal Injection

A.Signal Injection Scheme

The proposed design adopts a signal feed-through technique to improve IQ Mismatch. This scheme actually improves the “0” to “1” delay and thus reduces the disparity between the I and Q. However, there are three major differences that lead to a unique structure and make the proposed design distinct from the previous one.

I_a = I/Q amplitude imbalance

I_p = I/Q phase imbalance

IDC = in-phase DC offset

QDC = quadrature DC offset

Also let $x = x_r + j * x_i$ be the complex input to the block, with x_r and x_i being the real and imaginary parts, respectively, of x . Let y be the complex output of the block.

For DC offsets IDC and QDC

$$y = (y_r \text{PhaseImbalance} + IDC) + j * (y_i \text{PhaseImbalance} + QDC)$$

The value of the I/Q amplitude imbalance (dB) parameter is divided between the in-phase and quadrature components such that the block applies a gain of $+X/2$ dB to the in-phase component and a gain of $-X/2$ dB to the quadrature component where

X can be positive or negative. The value of the I/Q amplitude imbalance (dB) parameter is divided between the in-phase and quadrature components such that the block applies a gain of $+X/2$ dB to the in-phase component and a gain of $-X/2$ dB to the quadrature component where X can be positive or negative [6]. The Power Amplifier (PA) has linear input-output characteristic with gain $G_{PA} = 1$ and no memory effects. The RF stages can be modeled by the BPF block that includes all linear frequency-dependent effects; its baseband equivalent response is indicated as $h_{RF}(t)$. The complex envelope of the output signal $s(t)$ can be described as

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$$s(t) = h_C(t) * (z_I(t) + jh_{IQ}(t) * z_Q(t))$$

where the filter $h_C(t)$ is defined as

$$h_C(t) = h_{RF}(t) * h_I(t)$$

while the I/Q imbalance filter as

$$h_{IQ}(t) = h_M(t) * h_D(t)$$

Only $h_{IQ}(t)$ is responsible for the I/Q impairments since it distorts the Q branch signal, while $h_C(t)$ is applied to both in-phase and quadrature chains. The effects due to the combined I/Q imbalance in the TX and RX chains are discussed in [7]. I/Q estimation and compensation problem may be decoupled from the equalization one and solved separately. The above equation shows that the total I/Q mismatch can be modeled by a single complex filter

$$h_{IQ}(t) = h_{IQ,r}(t) + jh_{IQ,i}(t)$$

On the contrary, in [9] the authors used two complex filters to estimate the I/Q mismatch.

B. Figures of Merit

The most important figure of merit that characterizes the I/Q imbalance behavior of a device is the Image Rejection Ratio (IRR) [8]. The IRR value represents the power ratio between the desired and the image signals, and it is generally a function of frequency f_c and bandwidth B . If the IRR measurement is performed by using a single tone at frequency f , the front-end IRR is simply defined as

$$IRR(f) = |G_1(f)|^2 / |G_2(f)|^2$$

TX and RX performances are usually given in terms of Error Vector Magnitude (EVM) figures and not only IRR ones. In fact, EVM is determined by all RF impairments such as thermal/electronic noise (modeled as Additive White Gaussian Noise or AWGN for short), DC-offset, phase noise (PN), and non-linearity (NL) [7]. Using this technique, the imbalance parameters and the nonlinearity can be measured with less than 1-ms test time.

The highlights of this method are as follows:

- 1) determination of all IQ imbalances (gain and phase mismatch, dc offsets, and time skews) with a single setup and a single measurement;
- 2) determination of the IIP3 of the transmitter with the same setup and a second measurement;
- 3) nonlinearity computation is completely independent of the computed linear impairments;
- 4) analytical computation as opposed to using nonlinear solvers;
- 5) very efficient measurement with almost no computational overhead;
- 6) carefully designing test signals such that the effect of impairments can be separated;
- 7) using frequency-domain information to suppress the effects of undesired and/or un-modeled circuit effects;
- 8) high accuracy despite using only low-frequency

VI. SIMULATION RESULTS AND DISCUSSION

In the below figure shows that simulation result of proposed BER of the model. The BER computation is reset every 5000 symbols to allow you to view the impact of the changes in the model without having to restart the model.

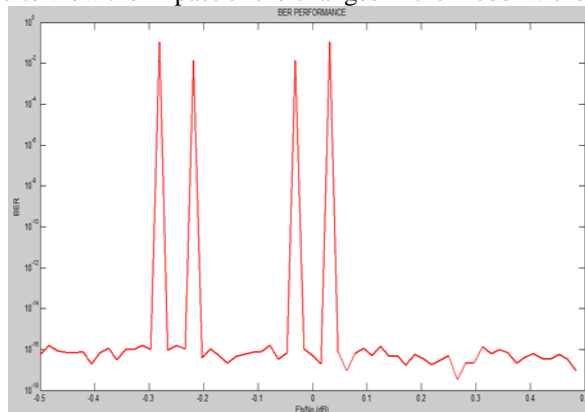


Fig 6.1. Simulation Results for BER vs SNR

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The power spectrum of the proposed transmitter is shown in below result.

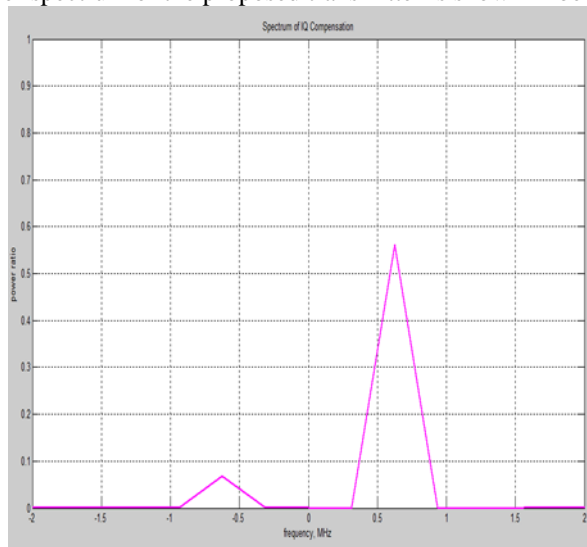


Fig 6.2. Simulation Results for power spectrum

The Image rejection ratio for gain and phase results for the transmitter is follows,

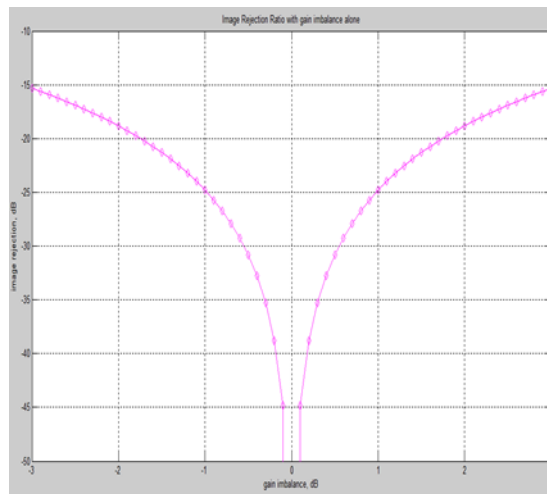


Fig 6.3 Simulation Results for IMRR- phase

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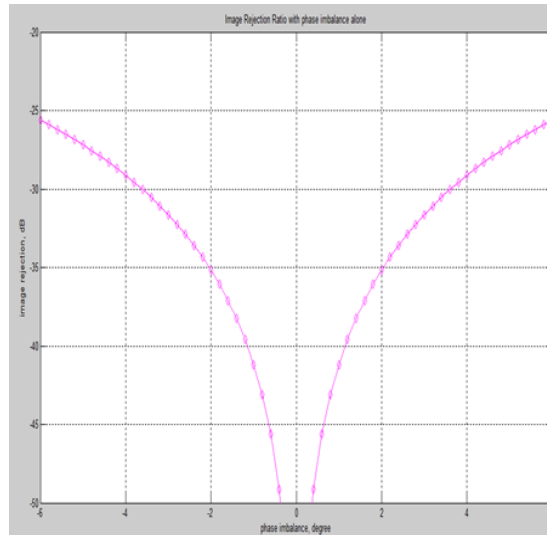


Fig 6.4 Simulation Results for IMRR- Gain

The root-mean-square errors for 500 instances using signal injection are shown in Table I. Table-I shows a comparative analysis of the proposed method with some of the state-of-the-art Signal injection techniques. Table 1. Comparison of various parameters

Parameter	RMS Error	Injection Limit
$\frac{G}{K}$	3.7%	[-6,8]
ϕ_{tx}	0.6°	[0°,5°]
g_{tx}	0.6%	[-20%,20%]
$DC_{I_{tx}}$	0.8mV	[0,50mV]
$DC_{Q_{tx}}$	0.75mV	[0,50mV]
$IIP3$	0.13dB	[10,15dBm]
τ_{dtx}	0.02ns	[0ns,5ns]

Compared with all existing techniques, the proposed method is the only available technique to compensate the IQ mismatch. Then the set of parameters displays acceptable accuracy.

VI.CONCLUSION

The development of this project is to describe the estimation and compensation of frequency selective I/Q imbalance effects in direct conversion transmitters for 3.5G/4G applications. I/Q imbalance estimation and compensation procedure has been derived and incoherent measurements are required for avoiding the need for time, frequency and phase synchronization between the transmitter and the RF measurement unit. I/Q imbalance problem can be modeled by a single complex filter whose coefficient may be estimated by exploiting an on-line or off-line architecture. Using different up-converter devices it shows that reduced complexity methods can be exploited to cut the costs of the compensation stages. To overcome this I/Q imbalance, signal injection method will be used. By using signal injection extra default signal is added in that gain and phase will be compared because of that mismatch occurred here will be reduced. The BER results of our proposed schemes are only within loss from an ideal system with perfect Knowledge of CSI (channel state information) and I/Q imbalance parameters.

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