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Distortion Issues in Direct Conversion Transmitters

Praju Prathap[1], L. Punitha[2]
[1]*Department of Electronics and Communication, Government Engineering college, Wayanad, Mananthavady-670644, Kerala, India*
[2]*Scientist-D, SAMEER- CIT Campus, 2nd cross Road,Tharamani-600 113, Chennai, India*

Abstract*—In the wireless communication systems, due to the increasing demands for high data rate and high efficiency, several practical challenges arise in the design of directconversion trans-mitters. According to the existing literatures, power amplifier (PA) nonlinearity and local oscillator (LO) pulling are the most critical factors to deteriorate the transmit signal quality. In this work, the above two issues are carefully investigated so as to improve the resultant distortion of the DCT output signal. An integrated approach for PA linearization and anti-LO pulling is designed.*

Index Terms*—Electromagnetic Compatibilty(EMC), Electro-magnetic Interference (EMI), Software defined Radio(SDR), Band Reject Filter(BRF)*

I. Introduction

Owing to the benefits of high integration and low power consumption, direction-conversion transmitter (DCT) is most commonly used in nowadays system-on-chip for modem wire-less communication systems. Achieving high-data-rate signal transmission for multimedia communications, especially in wide modulation bandwidth and high peak-to-average power ratio (PAPR), has led to stringent linearity constraints on signal conversion and amplificatio. The DCT consists mainly of a local oscillator (LO) to provide a pure sinusoidal signal and a quadrature modulator to perform the baseband IQ modulation, as well as a power amplifier (PA) to boost the transmitted signal power level. DCT distortion from the drawback of LO pulling effect as illustrated in Fig 1

In the early days, Adler and other authors studied the behavior of an oscillator under injection of an independent sinusoidal signal. In [2], the well-known Adler's equation was given to account for the injection locking phenomena in a free-running oscillator. Recently, there have been many approaches presented in the literature with prediction of the frequency pulling effects [4]-[6]. For instance, Razavi [4] considered a phase-locked loop under an independent sinusoidal injection.

This paper proposes a directly modulated self-injection PLL model to study the DCT pulling effects. By adding a self-injectionlocked loop to a PLL, the model can accurately account for the phase noise of a pulled LO, and subsequently the resultant modulation quality. Therefore, it can be used in design applications to optimize the PLL parameters for best output signal quality in a DCT that considers the LO pulling effects. In the experiment a very good agreement between the experimental data and predictions by the proposed model can be obtained.

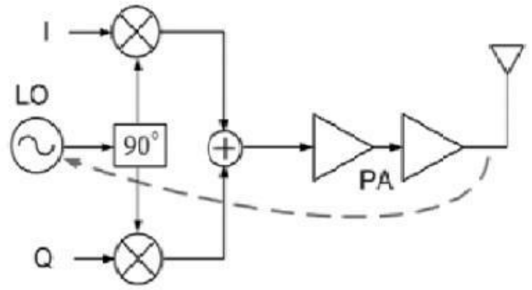

Fig. 1. Illustration of LO pulling effects

II. Theoretical Approaches

This section introduces the analytical model for a DCT with combined effects of PA distortion and LO pulling.

A. PA Distortion

PA is a key component for both user equipment and base station, responsible for amplifying the transmitted signal that arrives at the traget receivers with an adequate power level. The PA are inherently nonlinear.

B.LO Pulling The LO pulling effect has become a major distortion issue with the advances in integrated circuit (IC) process technologies. In the DCT architecture, the LO is nor-mally implemented by a phase-locked loop (PLL) to control the synthesized signals frequency and phase precisely, which is achieved by adjusting the voltage-controlled oscillator (VCO) output phase to align with the phase of reference signal.

III. Experimental Results

The transmitter uses direct-conversion architecture and mainly includes a LO, an IQ modulator, and a PA. The basedband I and Q component signals are provided by Agilent E4438C vector signal generator. Fig. 2 shows the experimental setup for testing the transmitter pulling effects, indicating that the power-amplified output signal is feedbacked to the VCO via a splitter, a delay line, an attenuator, and a circulator to serve as a self-injection signal into the LO. The transmitter output is connected to the spectrum and vector signal analyzer with the help of a coupler for simultaneously measuring the output spectrum and error vector magnitude (EVM). It is noted that the attenuator attenuation is controllable to adjust the

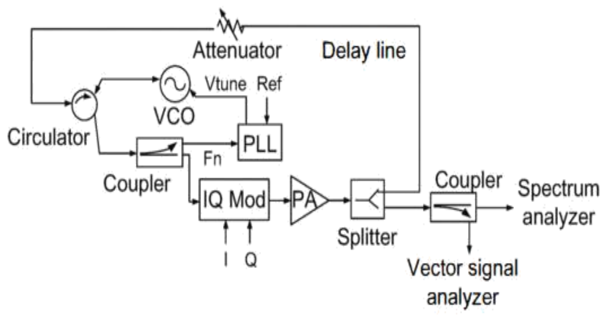

Fig. 2. Block diagram of the test setup for direct-conversion GMSK transmitter pulling experiments

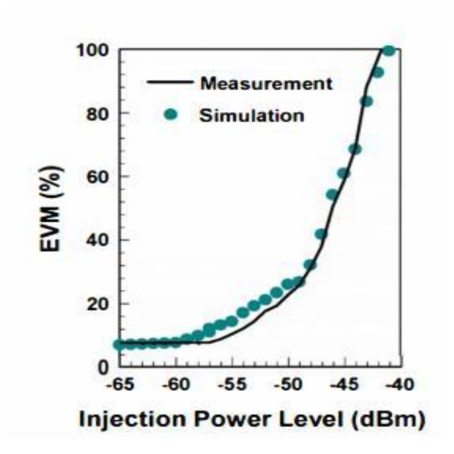

Fig. 3. EVM result

injection power level, and the circulator is used to isolate the self-injection signal from the LO output signal.

In the experiments, the LO is locked at 2.45 GHz, delivering an oscillation power of 1.5 dBm with an estimated natural frequency of 63 kHz. Firstly, an analysis was performed to observe the LO influenced by different selfinjection conditions. As mentioned, the transfer function shows bandpass filter frequency responses with the peak magnitudes located near the PLL natural frequency.

The experiment uses a modulated signal with a 270.833 kbps data rate as a self-injection signal to imitate the inter-ference from parasitically coupling of the P A output.predict the transmit signal quality from the LO phase noise. Fig. 3 shows the comparison between the measured and calculated EVM results.

IV. Conclusion

This paper studies the LO pulling effects on a direct-conversion transmitter. A model based on a directly modulated self-injection PLL is developed to account for and predict the degradation of phase noise and signal quality due to the pulling effects. The predicted results agree very well with the experimental data.

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