Automated IQ Mixer Calibration and Characterization Testbench

Graduate

Silvan Ammann

Introduction: Frequency up-conversion, a fundamental process often employed in radio frequency (RF) and microwave (MW) systems, shifts a signal from lower frequencies into a higher-frequency range. Traditional mixers used for this task require image rejection filters to suppress unwanted sidebands (SB), adding cost, space requirements and complexity. IQ mixers offer a filterless alternative, since they inherently suppress the image in single-sideband configuration. However, this approach poses two challenges: To achieve acceptable signal quality, both the image power and the leakage of the local oscillator (LO) must lie below a certain threshold. The SB suppression is maximized, by reducing the amplitude and phase imbalance between the in-phase (I) and quadrature (Q) signal. The LO leakage can be mitigated by applying a DC voltage at the I and Q port to prevent DC current flowing in the mixer, which would generate LO frequency output in the RF signal.
The goal of this thesis is to build an automated calibration testbench for IQ mixers, aiming to achieve a minimum LO and SB suppression of 60 dBc, within an LO frequency range of 2 up to 18 GHz and an intermediate-frequency (IF) signal bandwidth of up to 3 GHz. Using this testbench, the calibration limits of wideband IQ up-converters should be explored for two predefined mixer examples. Additionally, the influence of LO/IF frequency and temperature on mixer calibration should be characterized.

Approach: After identifying suitable instruments and components for the testbench, they are remotely controlled via a Python script. An algorithm aimed at finding the optimal parameter values for maximum SB and LO suppression is implemented. It iteratively narrows the parameter value search range until the best ones are found, as is visualized in Fig. 2. The IQ mixer is then characterized across the entire frequency range by optimizing the parameters at each frequency step. This process is repeated for different temperatures to characterize the effect of the temperature on the mixer performance.

Result: The automated calibration testbench functions effectively, calibrating and characterizing any IQ mixer rather efficiently. Both tested mixers demonstrate similar performance after optimization, meeting the required SB and LO suppression levels of 60 dBc. Fig. 3 presents a comparison of the calibrated suppression values of one of the mixers against its uncalibrated values. Both tested mixers performed similarly. The parameter ranges that achieve suppression levels of 60 dBc or more are remarkably narrow in comparison to the frequency-dependent changes of the parameters. For example, the I bias voltage varies between -100 and 10 mV over the entire frequency range, yet only ranges of around 0.8 mV achieve 60 dBc. Consequently, to maintain the desired suppression levels, parameters need adjustment whenever frequencies change. Additionally, because the optimal parameters are temperature-dependent, either a stable temperature must be maintained for consistent suppression or frequent recalibration is required.

Fig. 1: Picture of the automated calibration testbench.
Own presentment

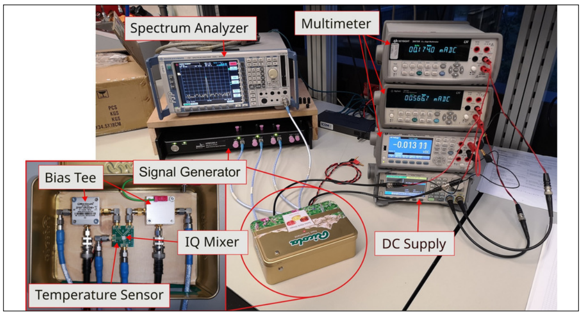


Fig. 2: I and Q DC voltage sweeps to find the values where the LO leakage is minimized.
Own presentment

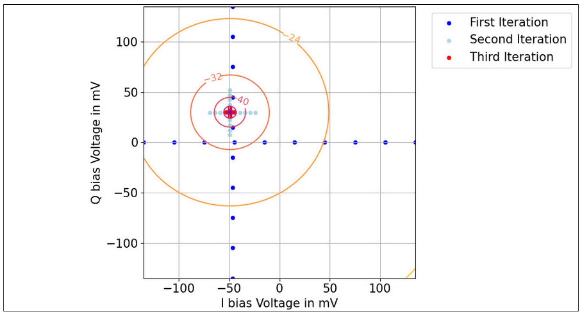
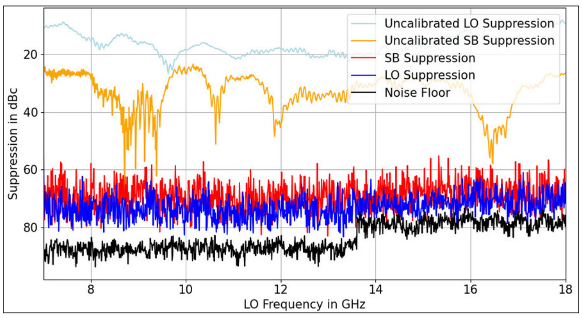


Fig. 3: IQ mixer calibration values over the LO frequency range.
Own presentment



Advisors
Prof. Dr. Hans-Dieter Lang, Nicola Ramagnano

Co-Examiner
Mischa Sabathy, SPEAG, Zürich, ZH

Subject Area
Wireless Communications

Project Partner
AnaPico AG, Opfikon, ZH