I/Q IMBALANCE CALIBRATION USING A GENETIC ALGORITHM APPROACH

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Abstract: Zero-IF architecture is one of the most integrated transmitter architecture, but I/Q imbalance can affect the transmitting performance and produce an unwanted mirror signal. To solve this problem, this paper proposes a calibration method of I/Q imbalance based on genetic algorithm (GA), which combines the additional loop-back path in the transmitter radio frequency (RF) end. In the digital baseband, the compensation parameters can be rapidly searched by using the global search capability of GA and the feedback information from loop-back path. The transmitting signal will be pre-compensated by using the obtained compensation parameters, so that I/Q imbalance can be calibrated.

Keywords: genetic algorithm; I/Q imbalance; I/Q imbalance calibration; transponder; transmitter.

Introduction

Micro-satellites are a new concept of satellites based on micro-electromechanical technology. They work in satellite networks through decentralized constellations. They work together to complete a wide range of mapping, stereoscopic imaging, distributed space measurements and many other tasks. In the future of scientific research and commercial applications, micro-satellites will play an important role.

In the view of the problem of I/Q imbalance, the existing studies can be divided into training sequence based method and blind estimation method. There are some papers based on ML criteria for joint estimation and compensation of transceiver I/Q imbalance [1]. Some papers also refer to a scheme that allows joint estimation and compensation of I/Q imbalance at the channel, transmitter and receiver [2]. The scheme has better performance only when the system has only I/Q imbalance, but once the system introduces interference such as frequency offset and the phase noise, the performance will drop rapidly. And the complexity of this scheme is relatively high. There are also some methods, which do not require the training sequences [3].

Aiming at the problem of the unbalanced transmitter I/Q branches, combined with the loop-back path of the transmitter RF end, this paper proposes a calibration method of I/Q imbalance based on GA. This method is suitable for I/Q imbalance calibration of the integrated transceiver chip with the loop-back path of the transmitter RF end.

The relationship between Sideband Suppression and I/Q Imbalance

Assume that the I-channel signal is a cosine signal and the amplitude is *A*. Assume also that the Q-channel signal is a sine signal and the amplitude is *B*. The phase difference between I-channel signal and Q-channel signal is *p(w)*. By derivation of the formula, it can be concluded that the difference between main signal and the mirror signal under the condition of I/Q imbalance, that is, the sideband suppression (SBS) is:

$$SBS = 10 \cdot \lg[\frac{A^2 - 2AB\cos(p(w)) + B^2}{4A^2}] \quad (1)$$

In order to simplify the description, it is assumed that *p(w)* is independent of the frequency, that is, the phase imbalance at each frequency component is the same, assuming *p'*. Then, SBS is:

$$SBS = 10 \cdot \lg\{\frac{1}{4}[(\frac{B}{A})^2 - 2\frac{B}{A}\cos(p') + 1]\} \quad (2)$$

As it can be seen from the formula (2), SBS can be used to measure the degree of I/Q imbalance. When I/Q imbalance is calibrated, the value of SBS will be infinite.

Calibration Scheme

A. The Architecture of Transmitter Calibration Scheme

The baseband signal frequency is set to f_b. The local oscillator (LO) frequency of the transmitter is set to f_{TXLO}. The LO frequency of the receiver is set to f_{RXLO}. Note that, f_{TXLO} should be slightly larger than f_{RXLO} and f_{TXLO} should be much larger than f_b.

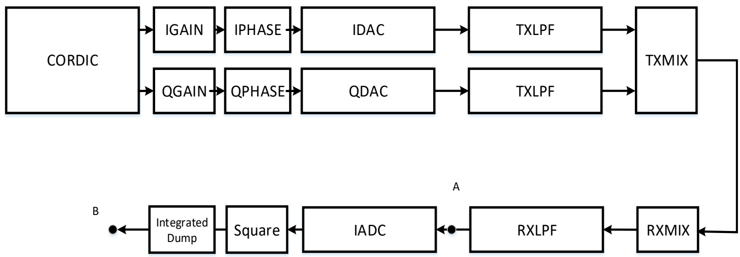

Fig.1. I/Q Imbalance Calibration Block Diagram.

As shown in Fig.1, the RF signal transmitted from the transmitter passes through the loop-back path and then is subjected to the low-pass filtering. At this point, the signal frequency at point A is f_{TXLO} - f_{RXLO} - f_b. Then, the signal at point A is sampled by the ADC module, and then through the square processing module and integrated dump processing module. Finally, the signal at point B can be used to indicate the degree of I/Q imbalance.

Therefore, the calibration of I/Q imbalance can be transformed into the following optimization problem:

$$\begin{aligned} \min \quad & f(I\_Gain, Q\_Gain, Phase) \\ s.t \quad & I\_Gain > 0 \\ & Q\_Gain > 0 \\ & \pi > Phase > -\pi \end{aligned} \tag{3}$$

where *I_Gain* and *Q_Gain* are the gain compensation parameter of I-channel and Q-channel, *Phase* is the phase compensation parameter, and function *f* is the signal strength at the point B.

In the ideal case, the above optimization problem has the unique minimum point. Using the algorithm, such as gradient descent method [4], the optimal solution of the optimization problem can be found. But in practice, there are multiple minimum points for the optimization problem due to noise and interference. At this point, the gradient descent method is no longer applicable because it is difficult to find the global minimum point. In this case, heuristic search algorithms, such as GA, can be used to find the optimal solution for the optimization problem.

B. Genetic Algorithm

GA is a random search algorithm that draws on the natural selection of natural circles and the natural genetic mechanism [5]. GAs are used to simulate reproduction, crossover and mutation in natural selection and natural inheritance. In each iteration, a set of candidate solutions is preserved and the better individuals are selected from the solution group by a certain metric. These individuals are combined using genetic operators (selection, crossover and mutation) to produce a new generation of candidate solution group. Repeat this process until a certain convergence criterion is met. Compared with the traditional heuristic optimization algorithm, the main characteristic of GA is the group search strategy and the simple genetic operator. The group search strategy enables then GA to break through the restriction of the search filed, so as to realize the distributed information collection and search on the whole solution space.

Scheme Simulation

A. Simulation Condition

This simulation uses MathWorks' Simulink software for simulation. The GA program used is from the Matlab Genetic Algorithm Toolbox, where the population size is set to 100 and the number of evolution is set to 64. In order to verify the effect of GA in this scheme better, a general gradient descent program is written as a comparison, where the search step is 0.0005, the termination precision is 0.000001 and the maximum number of searches is 15000.

B. Simulation results

The actual simulation results are shown in Fig.2. In the simulation, additive white Gaussian noise (AWGN) is added to the channel. Under the condition of high signal-to-noise ratio (SNR), the GA result is not much different from the optimization result using general gradient descent method. Under the condition of low SNR, the optimization result using GA is better than the optimization result using general gradient descent method. Because of the low SNR conditions, there are multiple poles in the optimization problem, which leads to the solution of the general gradient descent method easy falling into the local minimum point. Because GA has excellent global search ability, even if it falls into the local minimum point, it will quickly escape, so it can find the global optimal solution.

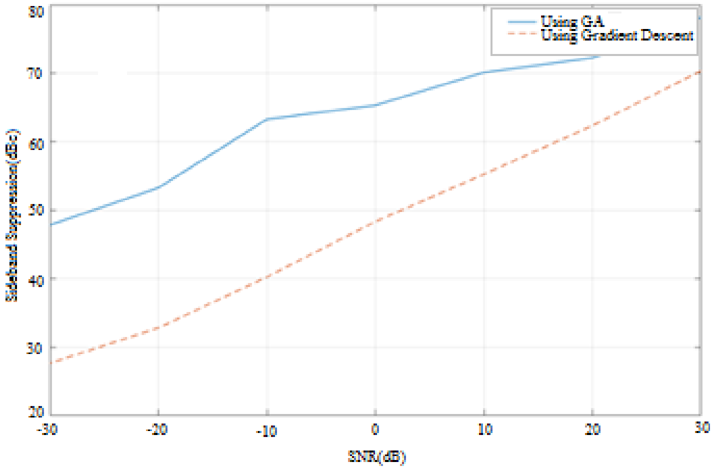

Fig.2. Sideband Suppression Using Different Method for Calibration.

Conclusion

By utilizing the loop-back path of the transmitter RF end, combined with the excellent global search ability of GA, the proposed method can effectively complete the calibration of I/Q imbalance of the transmitter. Compared with the traditional method, the proposed method is easier to implement.

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A NEW NONDESTRUCTIVE METHOD FOR DETERMINING THE COMPOSITION OF COMPONENTS IN BIOLOGICAL OBJECTS IN EXPRESS MODE

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Abstract. A new method for determining the components composition and their concentration in express mode in biological objects and liquid suspensions is proposed. It allows us to measure not only the relaxation constants T_1 and T_2, using which it is possible to determine the deviation degree of the medium from the standard state, but also the concentrations of the components included in the medium composition, at the site of sampling by a compact NMR spectrometer.

Keywords: Nuclear magnetic resonance, NMR, monitoring in the express mode, spectroscopy