Abstract

In-phase/quadrature (I/Q) signal processing is a fundamental tool in processing of bandpass signals. Especially in radio transceivers, it offers an effective solution to the inherent image signal problem without exhaustive RF image reject filtering, resulting in a clearly simplified analog front-end. This kind of approach is taken, e.g., in the so called low-IF receiver. When I/Q processing is implemented using practical analog electronics, however, the amplitudes and phases of the I and Q branches can never be perfectly matched. This compromises the theoretically infinite image signal attenuation in a dramatic manner, making it insufficient as such for most receiver architectures. Therefore, digital techniques enhancing this image attenuation play an important role in using simple analog front-ends in future high-performance highly-integrated wireless receivers.

In this thesis, novel I/Q signal processing techniques for wideband receivers are presented. The main emphasis is on the downconversion/demodulation process and the related image signal problem. The essence of the thesis concentrates on digital I/Q imbalance compensation. An analytical signal model for imbalanced analog front-end processing is derived and, based on this model, the imbalance compensation is formulated in a novel manner. The compensation problem is viewed as a signal enhancement task where two properly generated baseband observations are processed digitally. Two alternative digital techniques are proposed and analyzed. The first method stems from the well-known principle of adaptive interference cancellation whereas the second one is based on more recent blind signal separation. The compensation performance of both methods is studied analytically and using computer simulations. The results indicate that the proposed methods can provide sufficient compensation performance with reasonable assumptions. In general, since no known training signals are needed, the compensation can be performed blindly during the normal receiver operation. Furthermore, the most challenging situations of frequency-dependent and time-varying imbalances can be handled as well.

In addition to the digital enhancement of analog front-end image attenuation, bandpass sampling based digital quadrature demodulation techniques are also discussed. More specifically, a detailed analysis of the basic second-order sampling scheme is given and its connection to the ideal I/Q sampling is addressed. Due to the inherent timing offset between the I and Q branch signals, the resulting image attenuation of the second-order sampling scheme is limited and shown to be insufficient as such for multichannel signals. To improve the demodulation quality, fixed interference cancellation and fractional delay filtering based novel compensation techniques are proposed. As shown by the theoretical analysis as well as design examples, theoretical image attenuations in the order of 100 dB are easily achievable using either of the proposed approaches.