Surface acoustic wave (SAW) technology was invented more than a century ago. In modern telecommunication systems, SAW and bulk acoustic wave (BAW) technology have been widely adapted to build filtering devices (duplexers and filters) for radio frequency (RF) front end handsets due to its low cost and high performance. With deployment of third generation (3G) and fourth generation (4G) mobile networks in the recent decades, handsets are required to handle an increasing number of frequency bands with more complex modulation/demodulation schemes for more subscribers and higher data rate. These changes directly demand the more stringent linearity specifications to front end devices, such as SAW duplexers. However, in terms of duplexer design flow, in the past, empirical knowledge determined the design rules to meet the linearity specifications; a lack of predictability and understanding of nonlinearity root cause limited the improvement of the linearity of SAW devices. Therefore, research on the nonlinearity characterization and an accurate modeling of SAW nonlinearity for mobile device application are very essential. The research presented here primarily focuses on the development of a novel nonlinear Mason equivalent circuit model for SAW resonators/duplexers and on their nonlinear characteristics by measuring the harmonic and intermodulation distortions of the resonators. This model and the characterization results can be integrated into SAW duplexer design flows to help simulate the nonlinear effects accurately and improve the overall design.

In this dissertation, first, a novel nonlinear Mason equivalent circuit model including a third order nonlinear coefficient in the wave propagation is presented; next, SAW nonlinear distortions of SAW resonators and duplexers are analyzed by measuring large signal harmonic and intermodulation distortions on resonators using wafer probe station; and finally, the nonlinear Mason model is validated by comparing the simulation results with harmonic and intermodulation measurements on both resonators and a WCDMA Band 5 duplexer.

The Mason model developed is the first nonlinear physical model for SAW devices based on the equivalent circuit approach being presented. By using the nonlinear Mason model, good simulation measurement agreements are obtained for harmonics and intermodulation of both SAW resonators and duplexers. The outcomes of this research demonstrate the validity of the approaches both to characterize and to model the SAW devices. In particular, the work also confirms that 3rd order nonlinearity in the propagation, represented by a single coefficient, is a good assumption.