Unmanned aerial vehicles (UAVs) are remotely piloted or self-piloted aircraft that can carry sensors, communication equipment or other payloads. They are known for their ability to gather intelligence at safe stand-off ranges. The need of a sensor such as synthetic aperture radar (SAR) stems above all from the military requirement to be able to fight during the day and at night and in all weather conditions. Combining the atmospheric penetration and “24 hour” capabilities of radar and the high resolution similar to the one of an optical sensor, a SAR offers the ability to gather radar imagery of near-photographic quality in all conditions. High resolution SAR imaging, however, is hampered by the extra maneuverability and instability of these unmanned platforms. In such cases the complexity of the system emphasizes the need of computer-based simulations to exercise and measure in a controlled manner the full range of SAR performance. A major scientific problem in this context is the generation of SAR raw data in consideration of numerical and modeling accuracy, and restricted computer time and space. Therefore, the objective of this thesis is to create a novel raw data generation algorithm, capable of simulating the raw data set of an extended scene in a squinted spotlight mode taking platform motion errors into account.

For this work to succeed, it is of uttermost importance to fully understand the SAR raw data signals. Therefore the form and the properties of the SAR signals after their acquisition are detailed. The ability to implement platform motion errors demands a high level knowledge of these errors and thus of the SAR platform itself. The platform motion errors typical for UAVs are analyzed and the main components are identified and categorized. To have a clear insight into the interactions between the respective components of the platform motion errors and the SAR raw data signal, a motion error model is proposed. The main demand for such a motion error model emerges from the need to insert in a precise and flexible way platform motion errors in the SAR raw signal. The defined motion error model is validated through simulation: the model is proven to be representative of the effects of UAV motion.

The performances of a novel raw data generator (RDG) can only be analyzed after processing the created raw data and evaluating the obtained image. The RDG together with the processor are therefore placed in a simulation chain referred to as an end-to-end simulator for SAR systems on a generic UAV platform. The quality of the processing module is of particular interest for the outcome of the simulator. A comparison of the existing SAR processing algorithms, within a unified framework, allows to identify the \((\omega,k)\)-algorithm as the most precise for the use in an end-to-end simulator. Its digital implementation, however, becomes
rapidly time and memory inefficient for medium to high squint angles. Therefore, an enhanced version of this processing algorithm is used.

The core of this work is the presentation and the validation of a novel raw data generation algorithm. The existing SAR RDGs do not meet all the above defined requirements. Two novel RDGs are developed: the hybrid domain RDG and the approximated time domain RDG. The hybrid domain RDG is proven to be a computational efficient and precise simulation tool for squint angles up to 15° for an extended scene. Within this working domain the impact of platform motion errors is correctly simulated. The approximated time domain RDG is based on the same techniques as the hybrid domain RDG but offers the possibility to perform all the necessary operations in the time domain. Compared to the hybrid domain algorithm, this RDG has a lower computation time, a higher transparency of the code and it is easier to implement. However, this raw data generation tool is only meant for low-squinted geometries and allows a squint angle up to more or less 3°.

Overall, the created end-to-end simulator is a powerful tool for the investigation of the performances of high resolution SAR-UAV systems. The results of this analysis show amongst others the impact of the type of UAV used as the SAR platform. The influence of the squint angle on the impact of the different components of the motion errors is visualized and those contributing most to the final image degradation are identified.