Summary: Advanced Joined Detection and Synchronization Techniques

This thesis investigates the challenge of synchronization in coherent communication systems operating over time-selective channels. Coherent systems, known for their superior performance compared to non-coherent systems, rely on precise synchronization of phase, frequency, and timing between the transmitter and receiver. For many years, conventional receivers have relied upon the phase-locked loop (PLL) to achieve synchronization. PLLs are closed-loop systems that adjust the local oscillator's frequency and phase to align with the input signal. They have been widely adopted in various applications, including wireless communication and satellite navigation.

However, challenges arise due to variations in the channel caused by Doppler shifts, especially in scenarios with low signal-to-noise ratios. These conditions are common in deep-space communications, where residual carrier modulations are often employed to aid synchronization at the cost of power efficiency. Despite the simple design and ease of implementation of the PLL, it can struggle to or even fail in harsh propagation environments.

This thesis uses the factor graph and sum-product algorithm framework to focus on joint phase and frequency estimation. After establishing the foundation concepts and introducing the problem, a review of existing algorithms within this framework follows, examining their strengths and limitations in the context of time-selective fading channels. The purpose is to lay a foundation for deriving new detection and synchronization algorithms specifically designed for challenging propagation environments. These algorithms have been categorized based on whether they address phase noise alone or both phase noise and frequency uncertainties. These contributions aim to enhance system performance and reliability in adverse conditions, providing more robust solutions compared to traditional techniques.