# EXECUTIVE SUMMARY

The United States is currently conducting counterinsurgency operations against asymmetric combatants in Middle Eastern regions and worldwide. These combatants use unconventional tactics to execute deadly attacks on military and civilian targets coordinated through normal communications in a covert manner. The techniques this research proposes will prove beneficial in decoding intercepted communications of possible pre-emptive hostile actions. This matched filter approach to tracking phase shifts contained within Quadrature-Phase Shift Keyed (QPSK) signals provides a necessary capability to dissect PSK signals so decoding schemes can be employed.

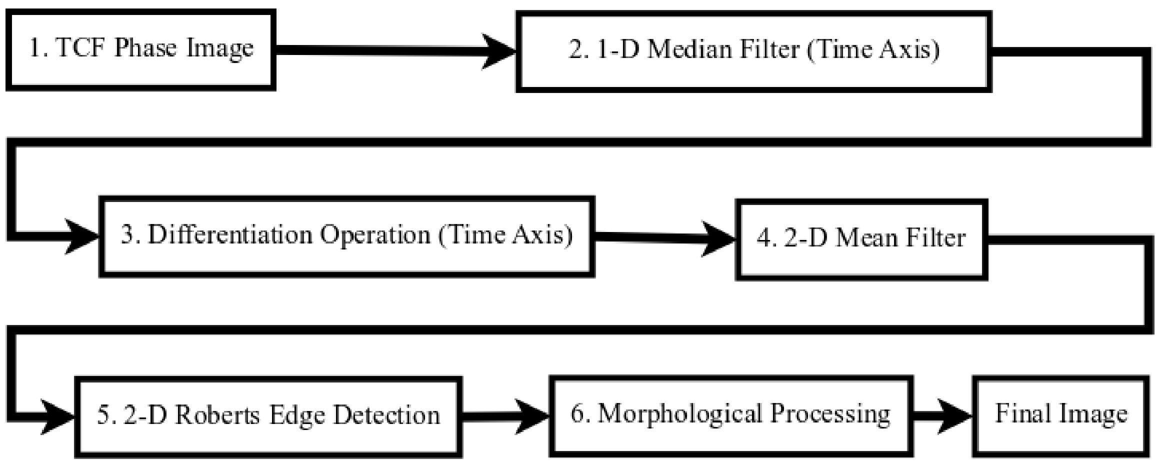
PSK signal encoding is applied in a number of applications in today's communications industry, including VHF and UHF television, FM radio, terrestrial and satellite microwave applications as well as short point-to-point experimental applications [1]. Wireless LAN as well as satellite communications require disciplined bandwidth conservation and make extensive use of Frequency Shift Keyed (FSK), Amplitude Shift Keyed (ASK), and QPSK types of compact signal generation and transmission schemes. The QPSK modulation technique was investigated because its bit encoding efficiency is commonly used to support modern communication requirements.

The Temporal Correlation Function (TCF) is a two-dimensional instantaneous complex symmetric auto-correlation function used to find the phase shift characteristic on a per-data frame basis. The objectives of this research were the following:

- Investigate an approach to identify phase shift timing within QPSK signals using image processing techniques and the Temporal Correlation Function (TCF) phase computation.
- Develop and test the image processing techniques required to remove noise from TCF phase images such that phase shifts are enhanced.
- Develop, design, and test the resulting phase shift identification scheme.

- Develop, design, and test an optional analysis window overlapping technique to improve phase shift detection rates in noisy environments.

The designed phase shift time detection scheme is split into two main phases. The first phase computes the initial TCF phase matrix and transforms it through a series of pre-processing filters and morphological operations into an image better suited for a matched filter solution. Second, the actual phase shift timing extraction task is conducted using a two-dimensional matched filter. Pre-processing phase steps used are summarized in the following flow chart.




Same as Figure 8. Start to Finish Image Pre-Processing Flow

The overall phase shift time extraction phase has two main components:

- A two-dimensional cross correlation matched filter operation, and
- An analysis window overlapping option designed to combine decisions obtained on separate windows and to improve performances in noisy conditions.

First, target images and structuring elements are defined followed by the TCF phase computation for each signal segment. These TCF phase images are then processed to isolate the phase shift timing before the two-dimensional cross-correlation locates the shift time in each window. Last, final phase shift time decisions are derived, either from individual decisions, or by combining multiple decisions when overlapping analysis is allowed during processing.

User-specified parameters are derived for QPSK signals in 6dB SNR environments and the resulting phase shift identification algorithm is investigated for SNR levels in the range -2dB to 12 dB. Detection performances are derived for 500 non-overlapping windows per experiment, where 250 windows include shift and no-shift cases, respectively, spread semi-randomly throughout the length of the signal when window overlapping is selected. The no-overlap window case did not use random placement to ensure only one shift or no shift per window. Results show detection performances are perfect for SNR levels 6 dB and above, and 95% detection rate are obtained between 4 and 6 dB SNR levels. Specific findings are listed below:

- Results obtained without overlapping analysis windows showed 99.2% accuracy rates at 6 dB.
- 60% and 90% window overlapping results showed detection performances are equal to 100% at the 10% tolerance level for 6 dB SNR level.
- Results showed the differentiation step implemented using the basic difference filter led to better detection performances than using the Savitzky-Golay (SG) FIR filter because the algorithm was designed for the difference filter. SG filters proved to obtain higher detection rates during high noise runs, however, false alarm rates caused by mismatched structuring elements during noise removal and phase shift transformation resulted in lower accuracy rates than the difference filter test results.
- Low and high normalized signal carrier frequencies were shown to have no direct impact on detection performances.

- Develop, design, and test an optional analysis window overlapping technique to improve phase shift detection rates in noisy environments.

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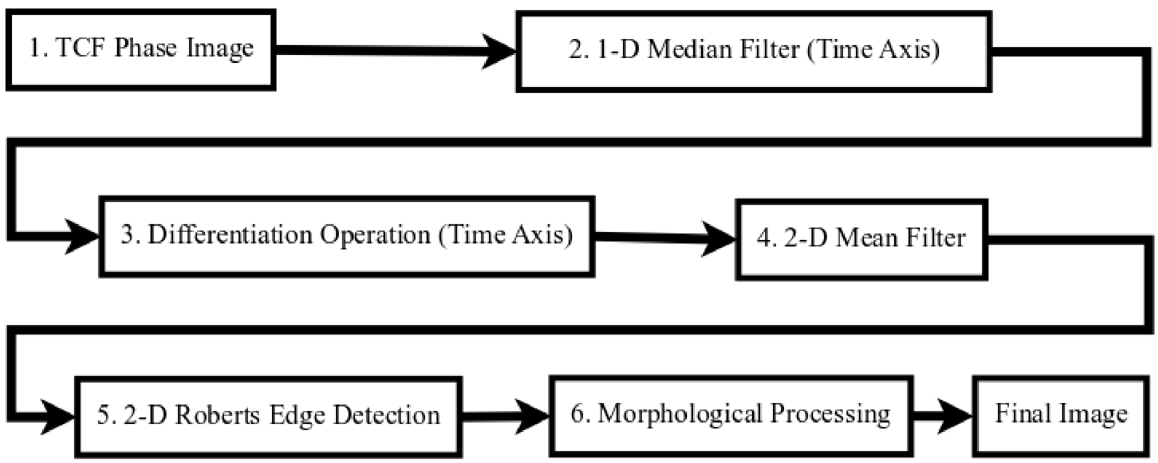


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