Abstract

Signals generated by fast moving acoustic sources are both challenging for analysis as well as rich in information. The motion is conceptually relative between the source and receiver i.e., either one of them is moving or both are moving. Thus, the receiver would gather information about the relative motion as well as the nature of source itself. For example, direction, velocity, acceleration, number of different sources, friend/foe, etc. are all information that can be gathered. All these parameters are inherently embedded in the received signal. Given the rich information content inherent in the signal, we address the task of extracting maximum information from minimum receivers, even a single micro- phone recording. By using more sensors with specific configurations, we can improve characterization of the moving acoustic source even better.

When we have a moving source generating a signal, naturally the Doppler effect comes into picture; the received signal becomes non-stationary with respect to its spectral content, even if the generated signal is stationary. This non-stationarity in the signal provides information about motion of the source. Oechslin et al. [24], through a series of experiments, demonstrated the role of Doppler effect as a fundamental principle for identification of direction of moving sound source. The authors illustrated the sufficiency of the Doppler effect to distinguish between an approaching or receding moving sound source. An interesting finding from their experiments is that observers are more sensitive to approaching sound sources than to those receding. This compelling result can be used to hypothesize interactions in biological systems, particularly the ones between predator-prey. Thus, the biological systems, with a minimal number of auditory sensors (2 ears), are able to extract valuable information from the source signal sufficient for their survival.

With the above motivation, we explore restricting the number of microphones used to estimate source parameters to a minimum. Since the Doppler effect manifests as time-varying frequency content in the signal, we use this non-stationarity to estimate source parameters. The thesis also addresses the issue of disambiguating the inherent source signal non-stationarity and the non-stationarity introduced due to the motion dynamics of the source. We also show analytically that these two kinds of non- stationarities can be decoupled under certain conditions. We next explore various methods of instantaneous frequency (IF) estimation from the received signal. In particular,

we use non-stationary signal processing tools such as the AM-FM model, time-frequency representations (TFRs), time varying- linear prediction (TV-LP) to aid the signal analysis. We explore in detail the effectiveness of chirplettransform and its variants with regard to the IF estimation and also discuss about the time-frequency resolution properties. We propose a new variant of the chirp let transform for multi-component non- stationary signals such as Doppler signals. We conclude the thesis by summarising our research contributions and throwing open various problems for pursuing further research in this field.