# STUDIES ON DIRECTION FINDING AND MOTION STATE ESTIMATION OF MANEUVERING AERIAL VEHICLE FROM ITS ACOUSTIC EMISSION

**by**

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## ABSTRACT

Aerial vehicles perform a crucial role in both commercial and military applications. Low flying aerial vehicles or aircrafts are also used for illegal activities across territorial borders due to difficulty in detecting the air vehicles by radar. Tracking of low altitude aircraft through radar systems is ineffective and costly in comparison with tracking via acoustic signature. Ground based sensors used for measuring acoustic signals of aircraft can be applied to detect, localize and distinguish targets.

The development of an acoustic attenuation simulation model is presented, that estimates the attenuation observed by the acoustic signal emitted by the aerial vehicle during its in-air propagation. Field experiments are conducted to analyze the efficacy of the model. It is concluded that results from the acoustic attenuation simulation model is comparable with measured acoustic attenuation when an acoustic source is moving with varying speed and altitude. The detailed analysis about contribution of environmental parameter variation towards transmission loss estimation can be used in providing uncertainty bounds due to imperfect environmental parameter knowledge, for motion parameter estimation of aerial vehicles.

An acoustic vector sensor (AVS) is designed and fabricated to estimate the direction of arrival (DOA) of the aerial vehicle. A p-p based AVS is developed and the design aspect of the same is described. The mathematical expressions for the estimation of elevation and azimuth angles in terms of the cross power spectrum density are given. Numerical simulation is performed for the DOA estimation of a single-frequency and quad-frequency acoustic source with varying signal to noise ratio (SNR) and microphone separation distance. The results show that the absolute azimuth and elevation angle error increases with an increase in microphone separation distance from the central microphone. Field experiments are also conducted where a tonal source and a quadcopter is flown, and its DOA is estimated from the emitted acoustic signal. The estimated results are compared with reference azimuth and elevation angles measured from Global Positioning System (GPS) values.

A time-frequency analysis is performed from the received acoustic signal and the present motion state of quadcopter is estimated. Field experiments are conducted, where a quadcopter is flown in different motion states and the acoustic signal emitted by the quadcopter is analysed for motion state estimation. An estimator is also developed for the state estimation of the quadcopter during flight. A motion state estimation table is presented for the estimation of quadcopter's states. The AVS positioned on the ground, estimates the DOA and motion state of the quadcopter. The efficacy of the estimator is also tested by flying the quadcopter in simulation mode and in field experiments, for deferent modes, i.e., in stationary or hover state and in forward/ backward motion state. Confusion matrix is also presented to analyse the efficacy of the estimator. It is observed that the estimator is effectively able to estimate the motion state with high level of accuracy.