Numerical Study of Source Localization using the TDOA Method

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The time difference of arrival (TDOA) positioning method is a classic method that is used to determine the unknown location of a transmitting wireless terminal, based on the time differences in the signals that are received at different receivers. In this research the method is studied for two- dimensional (2-D) problems for simplicity, for an electromagnetic dipole source radiating a carrier wave that is modulated by a baseband signal. By maximizing the cross-correlation between the signals arriving at any two receivers, the TDOA between these two receivers is estimated. In principle, only three receivers are needed for source localization in 2-D problems in the absence of noise, using the TDOA between any two pairs of receivers. The source is then constrained to lie at the intersection of two hyperbolas, arising from these two pair of receivers. Localization in the presence of noise is usually based on minimizing the square error between the measured TDOA between all possible pairs of receivers (multiplied by the speed of light) and the difference in distances between the estimated transmitter location and the corresponding pair of receivers.

In this research, a simple dipole source radiating a sinusoidal carrier wave modulated by a lower frequency baseband Gaussian signal is assumed, and the received signal at each receiver is obtained by using the exact transfer function obtained from the simple free-space frequency-domain dipole radiated electric field. After applying the TDOA method, the localization accuracy is studied with respect to varying parameters of interest, including: the sampling rate in the cross correlation, the bit quantization error in the analog to digital (ADC) conversion at the receivers, the number and location of receivers, and the way in which the signal processing is done (using the original (modulated) signals that are received or demodulating the signals before using them in the cross correlation).

The research also examines the localization accuracy with additive Gaussian white noise added to the signals. The result shows that the accuracy improves when the SNR (signal-to-noise ratio) improves, as expected. Furthermore, denoising methods such as local smoothing, coherent accumulation, and the averaging of the location vectors obtained via multiple trials are studied to improve the localization accuracy. Compared with the baseline result (without using any denoising methods), the localization accuracy greatly improves when using the denoising schemes, especially when the SNR is small, e.g., less than -20 dB.