Numerical Study of Source Localization with Non-Line-of-Sight Effects Based on Time Difference of Arrival 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 device, based on the time differences in the signals that are received at different receivers. In this investigation the method is studied for two-dimensional (2-D) problems for simplicity, using a vertical 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. However, the accuracy can be influenced significantly by non-line-of-sight effects when multiple walls, realistic ground effects, and scattering objects are added to the propagation route. A more accurate result can be obtained by using a modified method discussed here, which incorporates a transfer function that relates the field at a given receiver to the dipole source amplitude as a function of frequency. A "processed signal" is calculated at each receiver by de-embedding the transfer function from the received signals and multiplying back by a free-space propagation term for each frequency in the signal spectrum, thus removing the effects of the environment and calibrating the channel back to free space. Since the transfer function is different at each possible source position, an iterative method is proposed to do the localization.

In this investigation, a simple dipole source radiating a sinusoidal carrier wave modulated by a lower frequency baseband Gaussian signal is assumed. An infinite "front" wall with a given permittivity, conductivity, and thickness is added between the source and receivers to simulate a part of a building enclosure. Since the receivers are fairly far away from the source, the received signal at each receiver is obtained by using reciprocity and a simple transverse equivalent network method, which models plane-wave incidence from reciprocal sources located at the receivers. After applying the TDOA method combined with the proposed iterative method, the localization accuracy is studied with respect to varying parameters of interest, including the sampling frequency in the analog to digital converter, the wall parameters, and the sensor locations. The effects of added Gaussian noise are also studied.

Results show that the iterative method is quite effective at accounting for non-line-of-sight effects in the front wall model, where the error is only limited by the sampling frequency that is used in the cross correlation to find the TDOA values. Non-iterative methods can also be used, which prove advantageous when the iterative method fails to converge. The effects of a "back" wall located behind the source, in addition to the front wall, are also explored. In this case there are multiple reflections between the two walls, and hence this serves as a canonical situation where multiple reflections exist.