# Electromagnetic Orientation Using MIMO Channel Sounding in a GPS-Denied Environment

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For unmanned aerial vehicle guidance, when external positioning systems such as GPS are not available, alternate navigation methods must be used. Existing methods for self-localization, such as optical image registration, are limited to daytime operation and can be made non-functional by dust, smoke, or clouds. We propose a bio-inspired electromagnetic orientation (EO) technique based on multiple-input-multiple-output (MIMO) channel matrices for position discrimination that will allow localization in all weather conditions.

The EO navigation method is inspired by certain species of birds that use acoustic orientation to discriminate position and recognize a specific nesting area from among hundreds of other ones in a dark cave. Both the acoustic properties and RF propagation characteristics of a given environment are strongly position dependent. In particular, the MIMO propagation channel matrix defines the transfer function of the signal between the transmit and receive antennas, making it highly dependent on location and orientation. By comparing the matrices collected at various points to a database of pre-collected data, it is possible for a vehicle to self-localize.

Using a terrain scattering model, we showed that by comparing the norm of the difference of channel matrices, it is possible to recognize position at X band with centimeter-scale accuracy. Performance of the system varied significantly with the propagation characteristics of the environment. Low multipath environments produced less variation in the channel matrices, and channel matrix comparisons provided a radius of localization of several wavelengths. In contrast, tests in environments with strong multipath characteristics exhibited localization scales smaller than a wavelength. While localization on a centimeter scale is desirable for precision navigation, most applications require longer localization ranges to avoid missed waypoints. To increase the range of the EO method to $\sim$ 1 m, a comparison method based on the channel covariance matrix was developed.

To test the EO method experimentally, we employed a lightweight FMCW X band radar unit with one transmit and two receive antennas. The unit was mounted on a custom-built scanner unit that moved the radar platform in two dimensions. Experimental measurements exhibited similar properties to the simulations for both low- and high-multipath environments.

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