

# Accuracy of the TurfTrax Racing Data System for determination of equine speed and position

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*Carrier wave differential GPS system:* The accuracy of differential GPS (DGPS, see below) can be further improved by a technique involving analysis of the raw data from the individual satellites. GPS satellites broadcast on several frequencies, and dual frequency systems can receive signals on 2 of these frequencies and compare them, in order to produce more accurate position fixes. 'Carrier wave' refers to the part of the signal that the GPS receiver picks up. This approach can achieve a global position accuracy of 2 cm horizontally and 4 cm in height, is the 'gold standard for survey work', and is the technique used in this study.

*Chirps:* Brief pulses of radio-frequency signal that are emitted by the TurfTrax tags on the horse and detected at the base station receivers around the racecourse.

*DGPS:* Differential Global Positioning System. The GPS is a set of satellites in orbit about the earth that continually transmit microwave radio signals that can be picked up by a receiver on the surface of the earth and used to triangulate the current time, position and speed of the receiver. Differential GPS refers to systems that compare the signals received at two receivers on the earth, to improve the accuracy of the triangulation.

*Doppler information:* When a transmitter and receiver are moving either toward or away from each other, the frequency of the perceived radio signal will be shifted. Knowledge of a Doppler shift can be used to improve the accuracy of radio tracking systems.

*Dual Frequency GPS:* GPS satellites transmit signals at 2 different frequencies. Normal GPS receivers only use one frequency but higher quality receivers – often used by the military or for surveying work, will use both frequencies to enhance accuracy.

*Inertial sensors:* Sensors that measure the amount and orientation of the force experienced by a mass, for instance due to gravity (an inclinometer) or an external acceleration (change in speed or heading). They are typically used to identify things such as: 1) their orientation (tilt sensors); 2) impact events (e.g. car airbag triggers); 3) free fall (e.g. laptops that detect when they have been dropped and 'park' their hard drives in a safe position); and 4) to record a history of how and where they have been moved.

*Kalman filter:* The Kalman filter is a computational tool widely used in tracking, estimation, sensor fusion, and control applications when the underlying system dynamics can be

represented by a set of differential equations. A Kalman filter works by iteratively estimating the 'state' of a system, given a sequence of observations. It can incorporate data from data from diverse sensors into its estimate of the system, and uses statistical measures to smooth data and reject information that is noisy.

*MATLAB:* A software package for performing analysis, computation, and plotting of data (The Mathworks, Inc. Natick, Maryland, USA).

*Multipath:* The phenomenon of radio signals reaching an antenna by 2 or more distinct paths, often caused by reflection of signals off of objects such as buildings, water, or mountains.

*Pack blocking effects:* Situations in which horses may block the reception of chirps emitted by a tag from being received by certain antennae.

*Phase information:* In addition to measuring how large an oscillating signal is, the amplitude, it is possible to measure when the peaks and troughs in the signal are occurring, relative to some other time point. This is called the phase of the signal. Because of the way the atmosphere, reflections and interference of multiple signals can shift the phase of a signal, measurements of phase are useful in improving radio tracking. This is the primary technique employed within the TurfTrax tracking system.

*Radio frequency:* The frequency range of electromagnetic radiation, typically between 3 Hz and 300 GHz, that is often used in communications and tracking applications. GPS operates at 1.2 and 1.5 GHz, mobile phones at 1800 MHz, and FM radio around 100 MHz.

*Radio frequency tracking system:* A system that uses transmitters and receivers in the in the radio frequency range (3 Hz to 300 GHz) to track the movement of either the transmitter or the receiver.

*Videography:* The practice of recording video sequences and then analysing individual frames in order to extract data from them. This is typically done by tracking an identifiable point on the animal as it moves from one video frame to the next, and then using the size of a known calibration object in the movie to calibrate the distances that have been measured.