Fig. 11 Robot’s velocity profile estimation during the entire acquisition based on Doppler effect analysis. In red, ground truth velocity is obtained with filtered odometer data. In blue the estimates given by the method with the associated 1σ uncertainty is given.

standard deviation $\sigma_\nu = 0.76 \text{ m/s}$ and a mean $\bar{\nu} = 0.27 \text{ m/s}$. An error during the classical odometer recording occurred at the end of the trajectory, which explains the 0 values on the red data while Doppler is still estimating the velocity.

8.2 Detection and tracking of moving objects

Different experiments have been conducted with a GPS referenced vehicle in complex and noisy environment resulting in several false detections. During this experiment, the vehicle equipped with the radar is static. Each potential mobile object is tracked and updated based on Doppler observations. The evolution of the existence probability of each detection and their respective trajectories are presented in Fig. 12 and 13. Among the false detections, we can observe that their probabilities decrease quickly and then their tracks are deleted. Real mobile objects are tracked for a longer time and their probability increases at each new detection.

We can see two moving objects in the data: one at time $t = 25$ to 50 represented in red, the other one at time $t = 58$ to 78 in blue. Respective trajectories are represented in Fig. 13. Each track is plotted with the same color used in Fig. 12.

The trajectories of the two real moving objects are the two vertical straight lines. The accuracy of these tracks, both on position and velocity, has been processed based on D-GPS and proprioceptive sensor ground truth. The longest track (in red in Fig 12) is analyzed in Fig. 14. The tracking error of the moving object has a mean of 4 m in position and a mean error of 0.3 m/s in velocity.

Trajectories presented in Fig. 13 represent all the launched tracks. Two of them are due to real moving objects, while the remaining tracks are due to noises. Nevertheless, even if noise is important, their probability of existence is always decreasing and after 5 acquisitions (indeed 5 seconds) the majority of them are deleted as considered disturbances, while the remaining are confirmed as real mobile objects.

Tracking of multiple objects has been done in different formations (cf. Fig. 15): with vehicles in a convoy and also with vehicles crossing one another near the radar sensor. A total of four vehicles moved in the surroundings of the IMPALA sensor at various speeds. In the presented experiment, a convoy of three vehicles started from time 20 s to 30 s (cf. Fig. 16(a), (c) & (e)) and crossed a vehicle coming from the opposite direction at time 55 s (cf. Fig. 17 (a)). Then the three vehicles returned from time 110 s to 140 s (Fig. 17 (c), (e) & (g)). Trajectories and probabilities of moving objects from the first part of the experiment are given