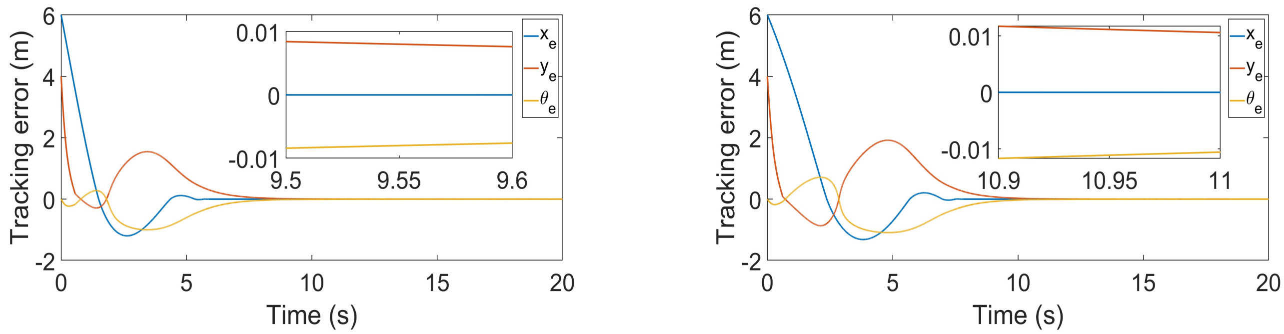
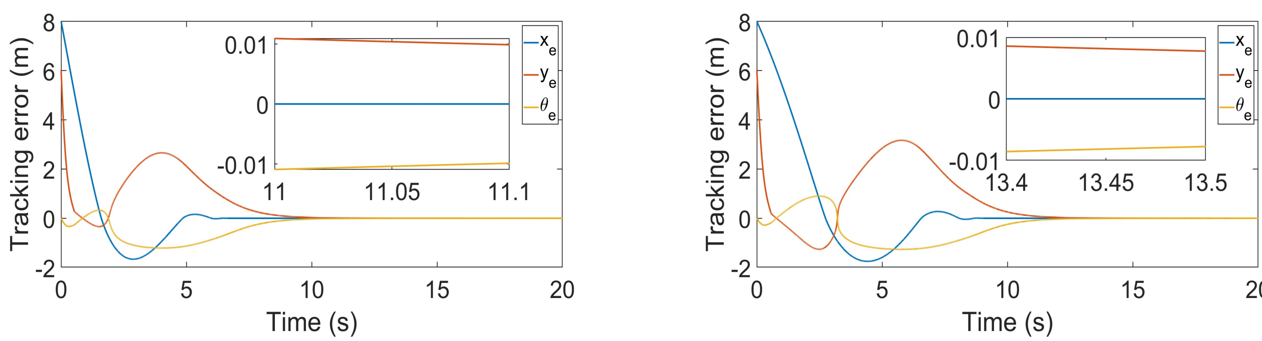
The acceleration effect of $-k_2 s(t_i)$ and $-k_4 \int_{t_i}^{t}(s(t_i))dt$ on the reaching phase

Theoretically, the main purpose of adding the $-k_2 s(t_i)$ and $-k_4 \int_{t_i}^{t}(s(t_i))dt$ is to provide the controller with exponential and integral convergence speeds. When the sliding mode variable $\|s\| > 1$, i.e., outside the unit circle, the convergence rate of $-k_2 s(t_i)$ is faster than that of $-k_1 \text{sign} s(t_i)\|s(t_i)\|^{\frac{1}{2}}$. In the initial stage of the control process, when the system states are far from the sliding surface, the addition of the $-k_2 s(t_i)$ provides an exponential convergence speed to facilitate the system state entering the sliding phase as fast as possible. The addition of $-k_4 \int_{t_i}^{t} s(t_i)dt$ is to provide an integral convergence speed, and its principle is quite similar.



(a) Our ET-STA. (b) ET-STA without $-k_2 s(t_i)$ and $-k_4 \int_{t_i}^{t} s(t_i)dt$.

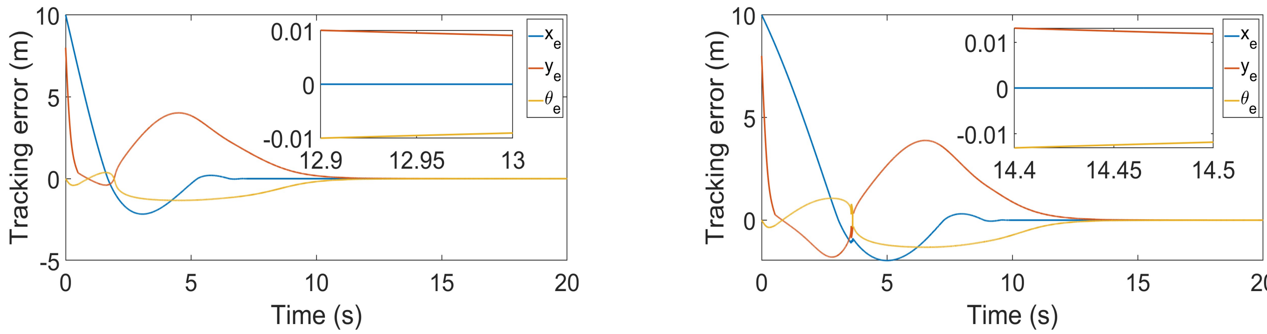
Figure 1: The tracking error of the reference WMR starting from (6,4).



(a) Our ET-STA. (b) ET-STA without $-k_2 s(t_i)$ and $-k_4 \int_{t_i}^{t} s(t_i)dt$.

Figure 2: The tracking error of the reference WMR starting from (8,6).

When the system state is far from the stable point, i.e., when the sliding mode variable s is significantly larger than 1 at the initial moment, we can more clearly observe the effects of $-k_2 s(t_i)$ and $-k_4 \int_{t_i}^{t} s(t_i)dt$. With the same control parameters selected, we demonstrate in Figs. 1, 2 and 3 the trajectory tracking errors of WMR starting from $(0, 0)$ to track the reference WMRs from different initial points. It can be observed that during the reaching phase, the convergence speed of our algorithm is faster than that of the algorithm without the



(a) Our ET-STA.

(b) ET-STA without $-k_2 s(t_i)$ and $-k_4 \int_{t_i}^{t} s(t_i)dt$.

Figure 3: The tracking error of the reference WMR starting from (10,8).

terms $-k_2 s(t_i)$ and $-k_4 \int_{t_i}^{t} s(t_i)dt$. Moreover, the further away the system states are from the stable point, the more obvious this effect becomes.