

# Comparison of the Radar and Seeker Modes of Pursuer Guidance

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This paper compares closed-loop performance of seeker-based and radar-based estimators for surface-to-air interception through 6-degree-of-freedom simulation using proportional navigation guidance. Ground radar measurements are evader range, azimuth and elevation angles contaminated by Gaussian noise. Onboard seeker measurements are pursuer–evader relative range, range rate also contaminated by Gaussian noise. The gimbal angles and line-of-sight rates in the gimbal frame, contaminated by time-correlated non-Gaussian noise with realistic numerical values are also available as measurements. In both the applications, extended Kalman filter with Gaussian noise assumption are used for state estimation. For a typical engagement, it is found that, based on Monte Carlo studies, seeker estimator outperforms radar estimator in terms of autopilot demand and reduces the miss distance. Thus, a seeker estimator with white Gaussian assumption is found to be adequate to handle the measurements even in the presence of non-Gaussian correlated noise. This paper uses realistic numerical values of all noise parameters.

## Nomenclature

$(a_{mx}, a_{my}, a_{mz})$	= pursuer inertial acceleration components	$(v_1, v_2, v_3)$	= radar measurement noise in Cartesian frame
$(a_{tx}, a_{ty}, a_{tz})$	= evader inertial acceleration components	$(\sigma_{ax}, \sigma_{ay}, \sigma_{az})$	= target acceleration uncertainty, Cartesian frame
$(K_{sl}, K_v)$	= seeker servo, track-loop gain	$(\sigma_{\phi_g}, \sigma_{\gamma_g})$	= random noise of gimbal angles, one $\sigma$
$(\mathbf{P}, \mathbf{P}_0)$	= system and initial state covariance	$(\tau_x, \tau_y, \tau_z)$	= target acceleration time constant lag
$(p, q, r)$	= body rates along body frame of pursuer	$(\phi_g, \gamma_g)$	= gimbal angles along inner gimbal frame
$\mathbf{R}_c$	= radar Cartesian noise covariance	$(\phi_l, \gamma_l)$	= evader line-of-sight angles (line-of-sight frame)
$\mathbf{R}_p$	= radar polar noise covariance	$(\phi_m, \gamma_m)$	= pursuer gimbal angles (inner gimbal frame)
$(r, \dot{r})$	= range, range rate (pursuer–evader relative)	$(\phi_r, \gamma_r)$	= evader yaw and pitch angle (inertial frame)
$(r_l, \dot{r}_l)$	= relative range, range rate along line of sight	$(\phi_l, \gamma_l)$	= evader line-of-sight rate (line-of-sight frame)
$(r_m, a_m, e_m)$	= measured range, azimuth, elevation	$(\omega_1, \dots, \omega_9)$	= process noise components in radar estimator
$(r_t, a_t, e_t)$	= true range, azimuth, elevation	$(\omega_{gz}, \omega_{gy})$	= line-of-sight rate of evader along inner gimbal frame
$T_s$	= radar estimator sampling time		
$(V_c, V_m, V_t)$	= closing, pursuer, evader velocity		
$(V_{mx}, V_{my}, V_{mz})$	= pursuer velocity, inertial		
$(V_{tx}, V_{ty}, V_{tz})$	= evader velocity, inertial		
$(V_{xe}, V_{yn}, V_{zu})$	= pursuer velocity (east, north, up)		
$(w_{a_{tx}}, w_{a_{ty}}, w_{a_{tz}})$	= Gaussian acceleration process noise		
$(\mathbf{X}, \mathbf{X}_0)$	= system and initial state vector		
$(x_m, y_m, z_m)$	= pursuer inertial position components		
$(x_t, y_t, z_t)$	= evader inertial position components		
$(\Delta V_x, \Delta V_y, \Delta V_z)$	= pursuer, evader relative inertial velocity		
$(\Delta x, \Delta y, \Delta z)$	= pursuer, evader relative inertial position		
$(\varepsilon_y, \varepsilon_p)$	= gimbal angle tracking error (yaw, pitch)		
$(\eta_y, \eta_p)$	= demanded latax (yaw, pitch)		
$(\mu, \sigma)$	= mean and standard deviation		
$v_k$	= innovation during the $k$ th measurement		

## Introduction

IN AN air combat scenario, the pursuer–evader guidance problem is generally solved by the proportional navigation (PN) principle. In real-world radar-based guidance, evader range, azimuth and elevation angles as measurements are assumed to be contaminated by Gaussian white noise. They are processed to estimate evader position and velocity by an extended Kalman filter (EKF) based state estimator and are uplinked to the pursuer to generate onboard guidance commands [1]. Similarly, in real-world seeker-based guidance, the pursuer onboard active radio frequency seeker measures pursuer–evader relative range, and range rate contaminated by assumed Gaussian white noise. The gimbal angles and relative line-of-sight (LOS) rates in the inner gimbal (IG) frame are also available as measurements contaminated by non-Gaussian colored noise. Further, LOS rate noise is high due to glint, radar cross section (RCS) fluctuation, and thermal effects. Corresponding signal-to-noise ratio (SNR) in LOS rates vary from a low value of 3 dB to a high value of 50 dB. This is a function of range to go from evader lock on until interception. Also, in a seeker with a single high pulse repetition frequency, signal loss occurs due to eclipsing. This results in intermittent data loss in LOS rate measurements. Under these conditions, the seeker estimator has to estimate pursuer–evader relative state

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