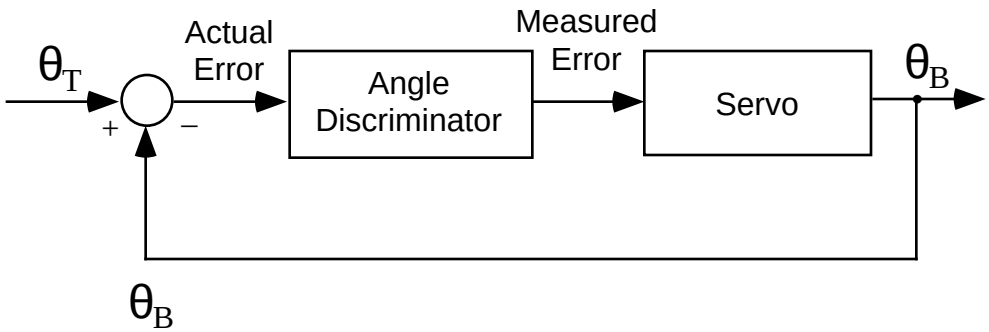
3.27 ANGLE TRACK

The function of angle track is to continuously aim the radar antenna boresight at the target's true angular position. Two major components are imbedded in the angle track loop illustrated in Figure 3.27-1: the angle discriminator and the element which repositions the antenna boresight.

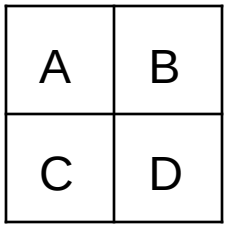


q_T = True angle-to-target
q_B = Measured angle-to-target

FIGURE 3.27-1. Angle Track Loop.

The angle discriminator determines the error between the target and antenna boresight and sends a corrective command to the servo. This discriminator can be of the classical or modern type. Examples of the former type of discrimination are the conical scan and track-while-scan systems. These systems scan in the area of the target and find the centroid of the returned energy. The difference between the centroid and boresight is used as the updated command to the servo.

Modern angle tracking is provided by monopulse systems. These systems can accumulate all of the data needed for track update based on a single pulse return. As illustrated in Figure 3.27-2, one sum channel and two difference channels are used to extract repositioning data in both azimuth and elevation.



Sum = A + B + C + D

Up – Down = (A + B) – (C + D)

Right – Left = (A + C) – (B + D)

FIGURE 3.27-2. Monopulse Tracking.

RADGUNS employs a subroutine to simulate the antenna servo system, moving the antenna in response to error signals from the receiver. Once each scan or set number of pulses, the radar receiver model computes two tracking angle error signals and sends them to this routine to calculate the response of the antenna servos. The azimuth error signal and the current antenna boresight azimuth are input to the azimuth servo model, yielding a new

value for the antenna boresight azimuth. The elevation error signal and antenna boresight elevation are treated in an analogous manner.

Radar measurement of target position and velocity is based on the assumption that some point on the target may be defined as the position reference. Reflections from different elements on a complex target cause the apparent shift in target coordinates as a function of changing aspect angle. This error, known as glint, may significantly degrade tracking performance, especially while tracking large targets at close range. Small targets at long range appear as point sources with little or no tracking error attributed to glint.

Data Items Required

Data Item	Accuracy	Sample Rate	Comments
7.1.1	Tracking azimuth	±0.1 deg	10 Hz
7.1.2	Tracking elevation	±0.1 deg	10 Hz
7.1.3	Actual azimuth	±0.1 deg	10 Hz
7.1.4	Actual elevation	±0.1 deg	10 Hz

3.27.1 Objectives and Procedures

Angle track is sensitive to rates of change in the angular position of the target. These rates are affected by target size, speed, and range from the threat.

RADGUNS was executed with the following input conditions:

a. Model mode: SNGL/RADR/MTI OFF
b. Target radar cross section: 0 dBsm
c. Target presented area: 1.0 m2, 10.0 m2
d. Target speed: 50, 150, 300 m/s
e. Target flight path: LINEAR
f. Guns: Disabled
g. Output: Azimuth and elevation tracking errors

Targets with presented areas of one square meter and ten square meters were flown within tracking range of the radar at speeds of 50, 150, and 300 m/s. Beginning at a range of 7000 m, the target flew toward the radar, then away, crossing over approximately halfway through the flight. Different offsets from the radar were used to vary the stress on the angular tracking response of the system.

To perform a linear analysis of angle tracking errors, all angle errors were converted to linear (distance) errors computed at a specific target range. Angle error in meters is the product of slant range to the target in meters and the sine of the angle error in radians.

3.27.2 Results

Plots of azimuth and elevation error time histories were made for each run to examine the effect of target size, speed, and offset on tracking error characteristics. Azimuth error versus time plots are depicted in Figures 3.27-3 through 3.27-8 for the two target sizes (one

and ten square meters, labeled TPA1 and TPA10, respectively) at offsets of 1000 and 2000 meters.

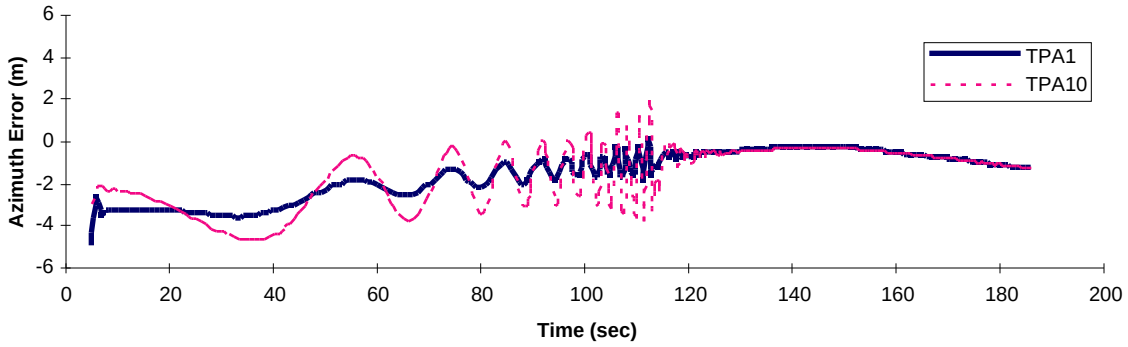


FIGURE 3.27-3. Azimuth Tracking Errors for 50 m/s Target at 1 km Offset.

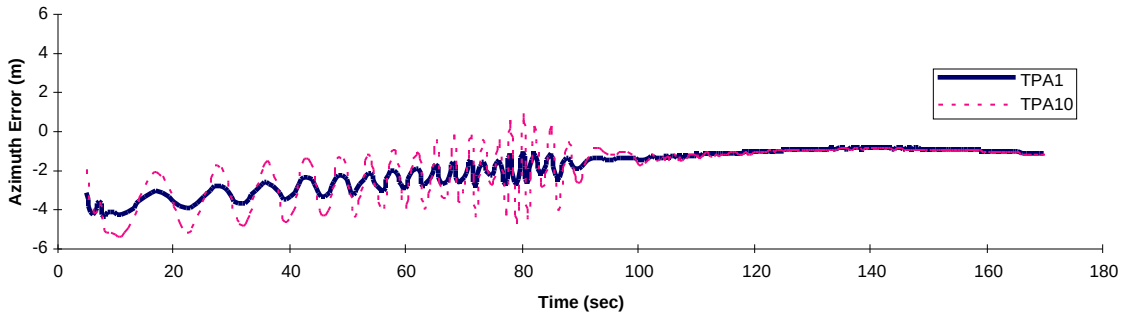


FIGURE 3.27-4. Azimuth Tracking Errors for 50 m/s Target at 2 km Offset.

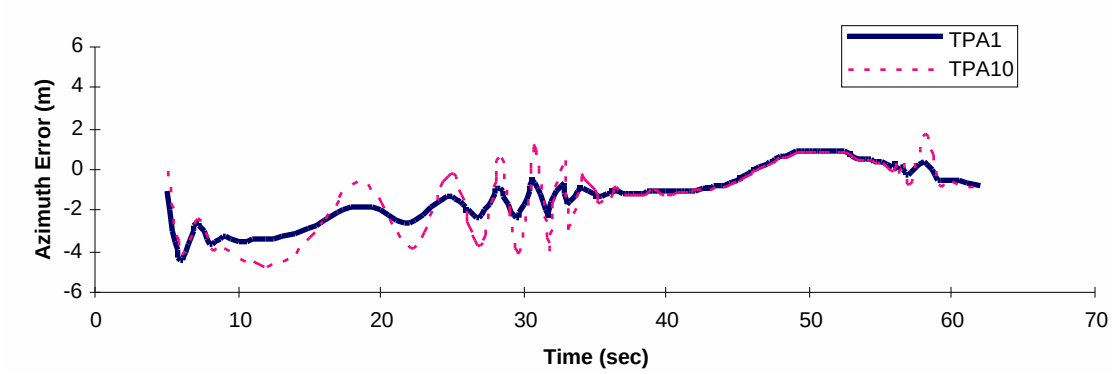


FIGURE 3.27-5. Azimuth Tracking Errors for 150 m/s Target at 1 km Offset.

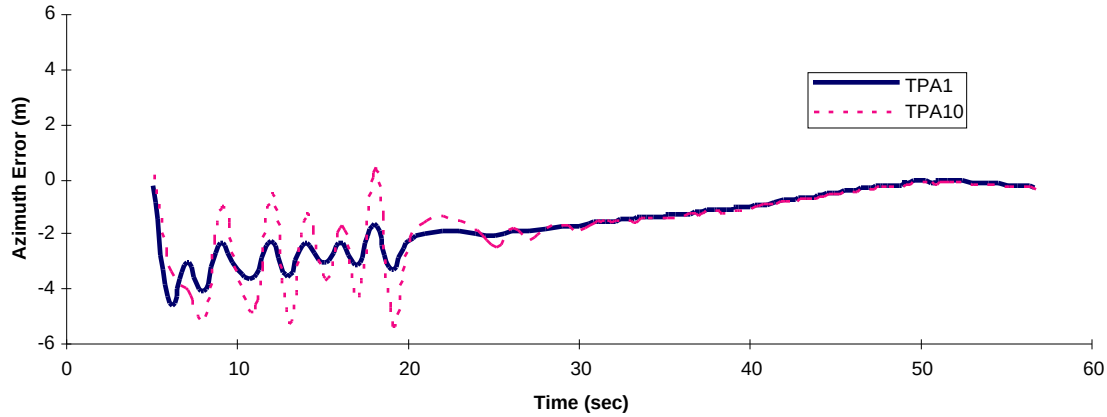


FIGURE 3.27-6. Azimuth Tracking Errors for 150 m/s Target at 2 km Offset.

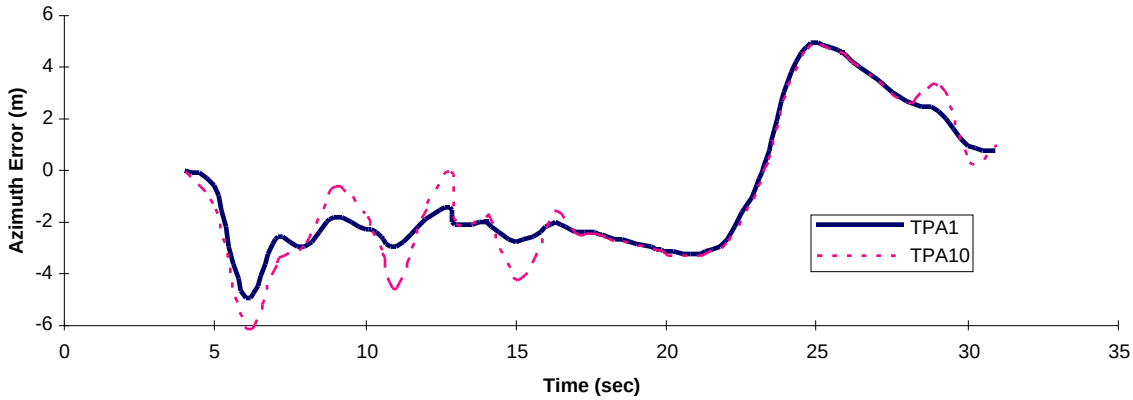


FIGURE 3.27-7. Azimuth Tracking Errors for 300 m/s Target at 1 km Offset.

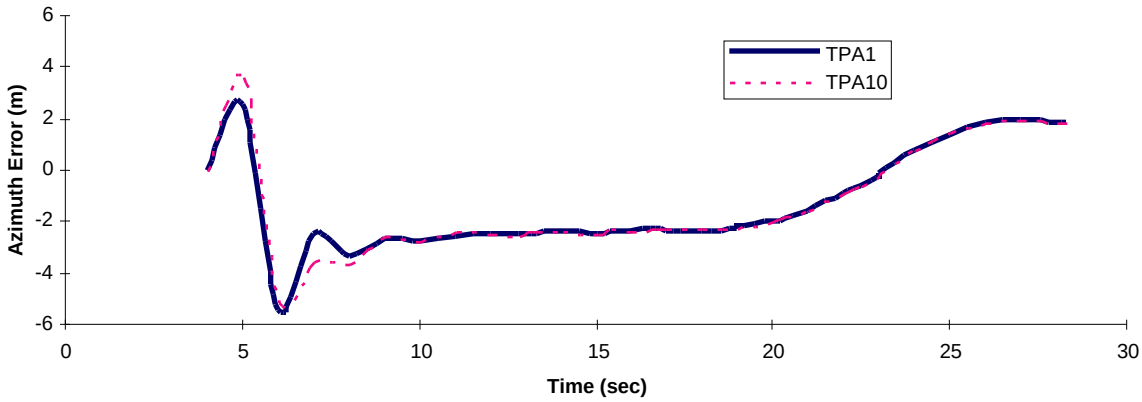


FIGURE 3.27-8. Azimuth Tracking Errors for 300 m/s Target at 2 km Offset.

Figures 3.27-3 through 3.27-8 above show the effects of target speed and size on azimuth angle tracking at two offsets. Azimuth tracking error is inversely proportional to target range for the inbound portion of each pass. This effect becomes more prominent at higher target velocities. The azimuth tracking errors become increasingly more positive when the target speed increases as the radar antenna boresight lags behind the target. An increase in target presented area also contributes to an increase in azimuth tracking errors. This increase is inversely proportional to target speed. At 50 m/s, target size is the main contributor to the azimuth tracking error, but at 300 m/s it has little or no effect.

The combined effects of target range, speed, and size are shown in Figure 3.27-9, which shows the root-mean-square (RMS) azimuth tracking error output of *RADGUNS*. The RMS azimuth tracking errors generally decrease as the target comes closer to the threat radar. After crossover, the cumulative azimuth errors increase as the range to target increases. The tracking errors increase as target size increases. This effect is most prominent for slow moving targets.

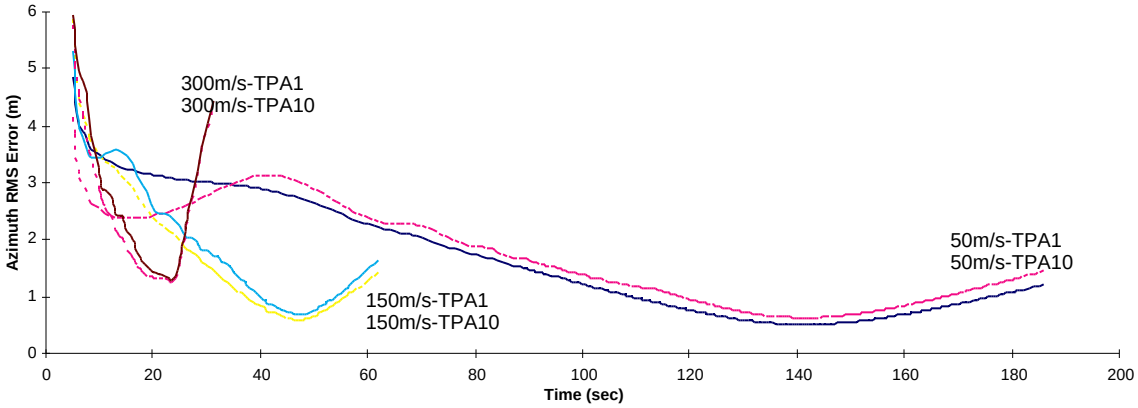


FIGURE 3.27-9. RMS of Azimuth Tracking Errors.

Figures 3.27-10 and 3.27-11 show the effects of tangential velocity and target size on azimuth tracking error. Target speed shapes the error distribution while target size scatters it. Target size has an significant effect at 50 m/s while causing little effect at 150 m/s and 300 m/s.

An increase in tangential velocity results in an upward (more positive) shift in the mean for each error distribution as shown in Figures 3.27-12 through 3.27-14. For both the one square meter and the ten square meter targets, the mean shifts from approximately -1.25 to -0.652 meters with increasing speed.

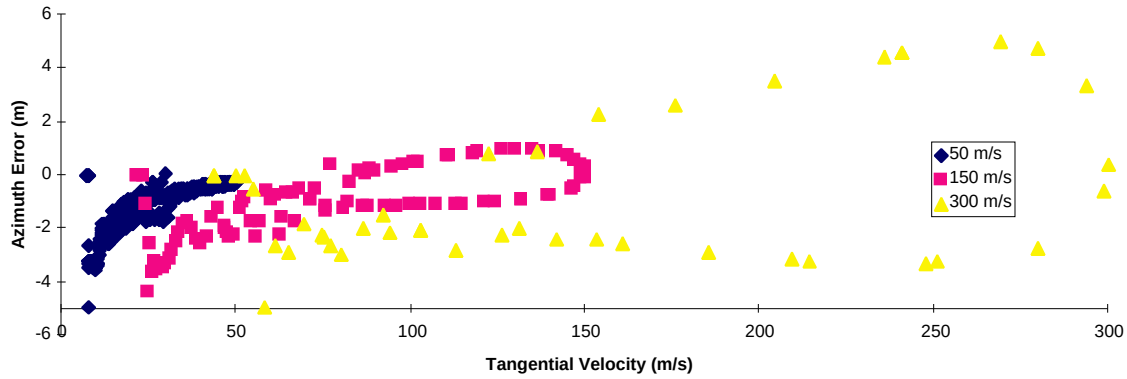


FIGURE 3.27-10. Azimuth Tracking Errors as a Function of Tangential Velocity, $1m^2$ Target, 1 km Offset.

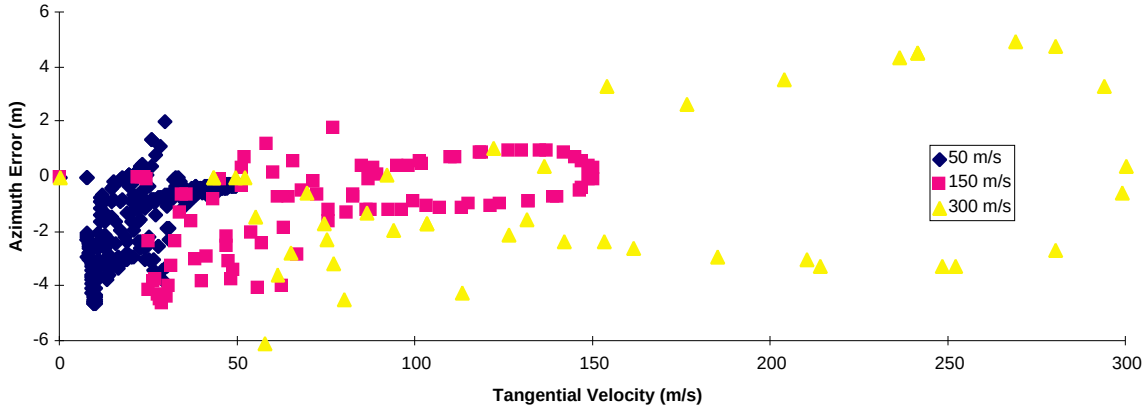


FIGURE 3.27-11. Azimuth Tracking Errors as a Function of Tangential Velocity, $10m^2$ Target, 1 km Offset.

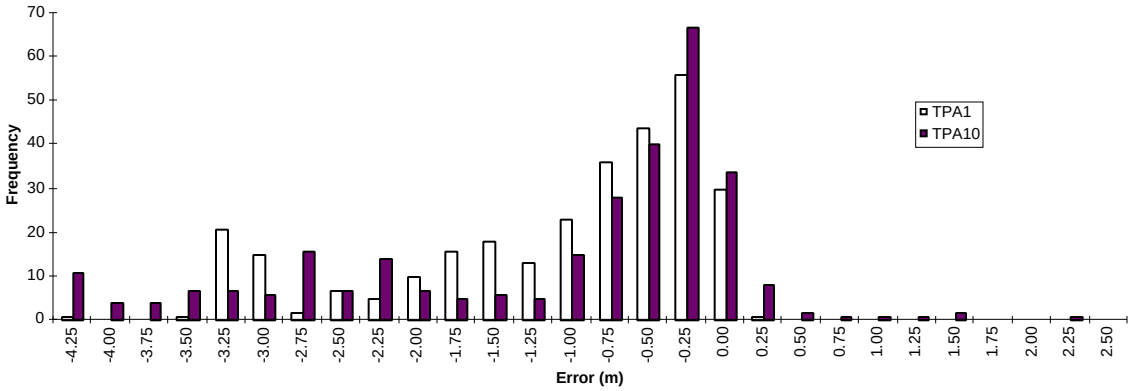


FIGURE 3.27-12. Distribution of Azimuth Track Errors for 50 m/s Target.

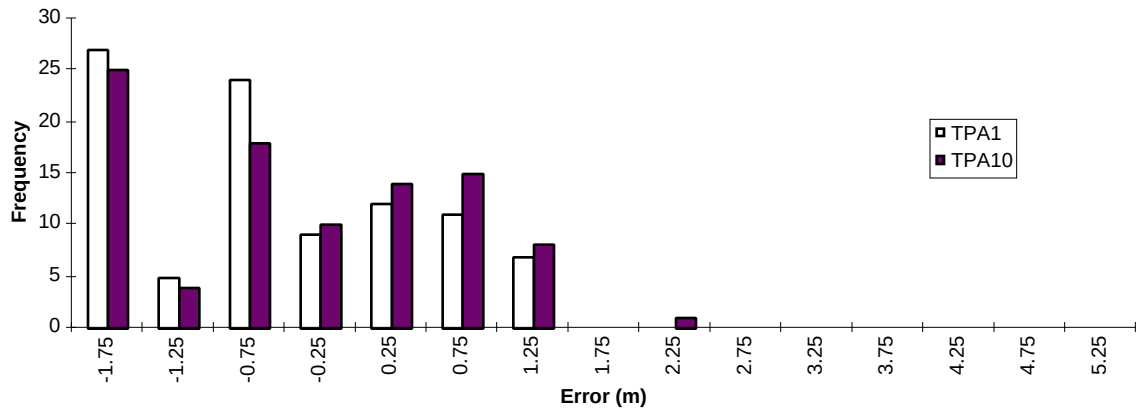


FIGURE 3.27-13. Distribution of Azimuth Track Errors for 150 m/s Target.

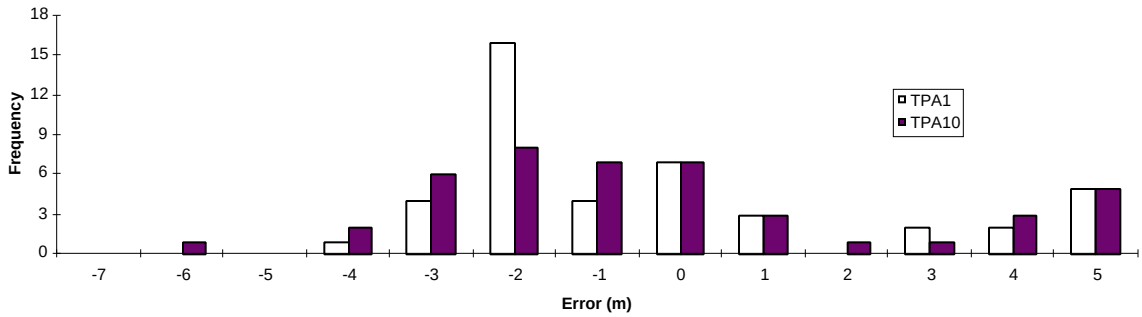


FIGURE 3.27-14. Distribution of Azimuth Track Errors for 300 m/s Target.

Elevation error versus time plots are depicted in Figures 3.27-15 through 3.27-20 for one square meter and ten square meter targets at offsets of zero and 1000 meters. These figures show the effects of target speed and size on elevation tracking errors. Target size has very little effect on the elevation tracking error. An increase in target speed results in a slight decrease in the mean elevation tracking error for both the one square meter and the ten square meter targets.

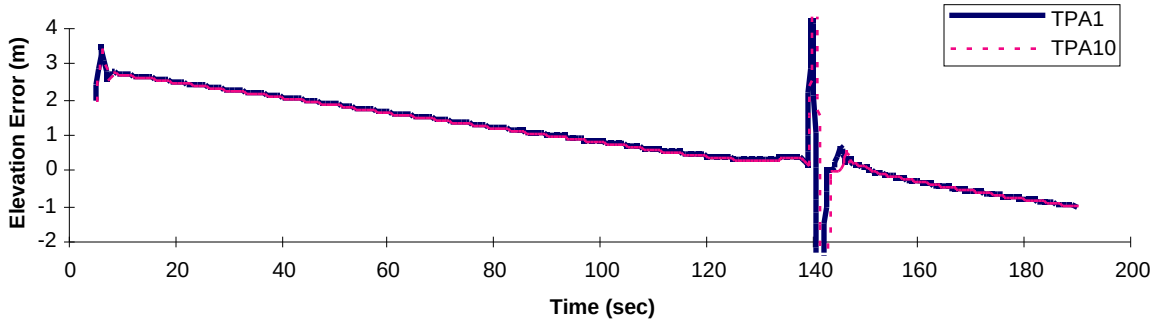


FIGURE 3.27-15. Elevation Track Errors for 50 m/s Target at 0 Offset.

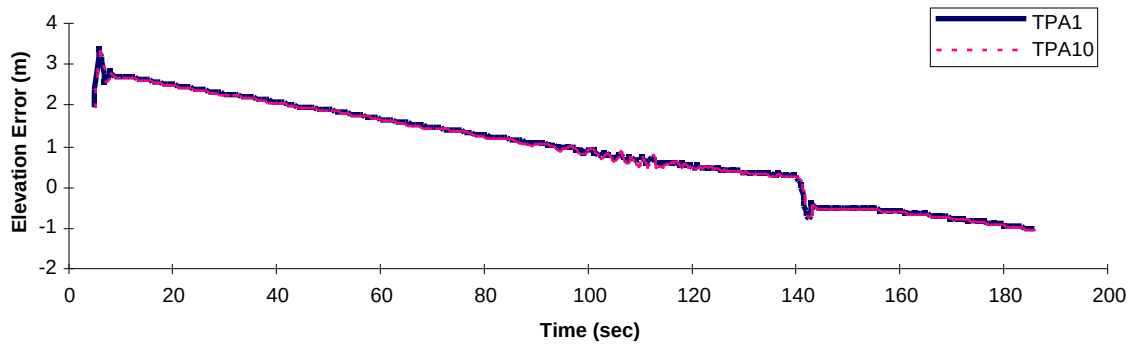


FIGURE 3.27-16. Elevation Track Errors for 50 m/s Target at 1 km Offset.

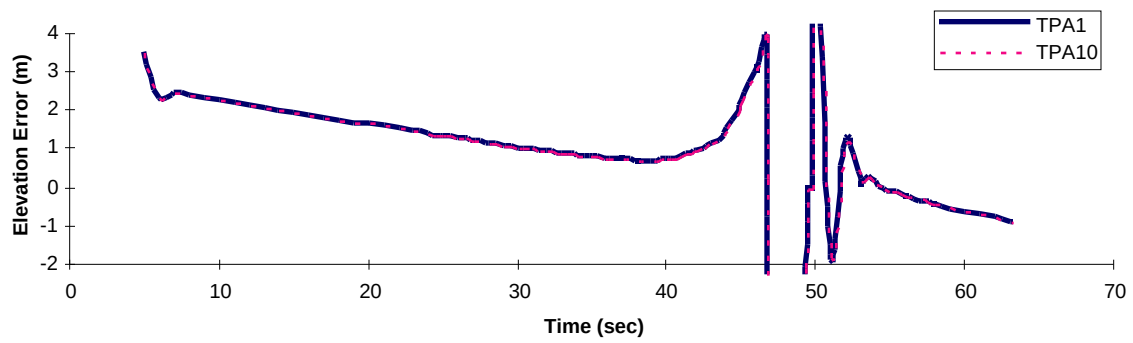


FIGURE 3.27-17. Elevation Track Errors for 150 m/s Target at 0 Offset.

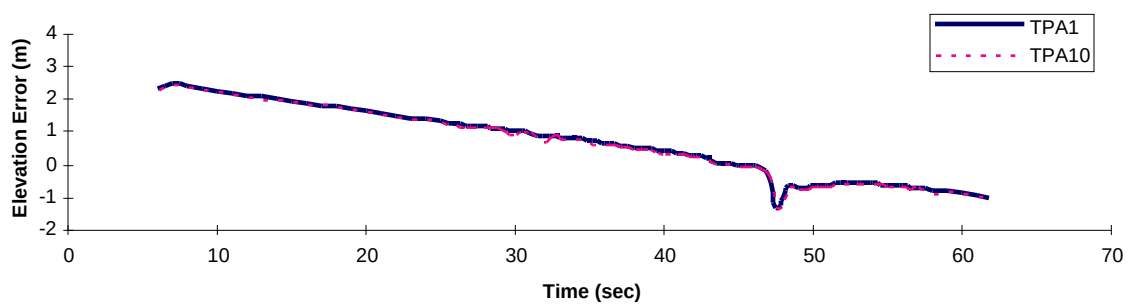


FIGURE 3.27-18. Elevation Track Errors for 150 m/s Target at 1 k/m Offset.

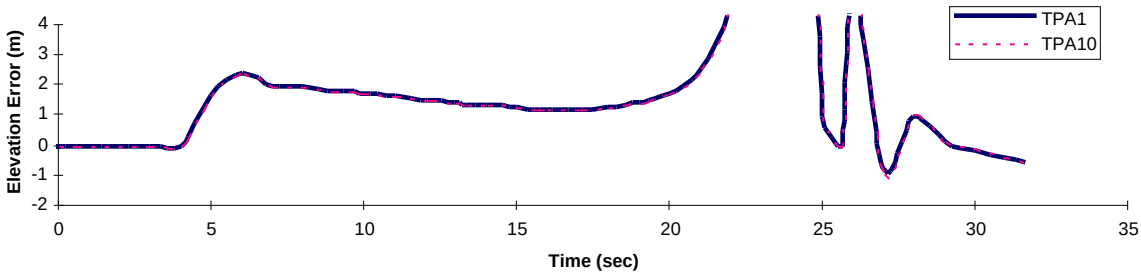


FIGURE 3.27-19. Elevation Track Errors for 300 m/s Target at 0 Offset.

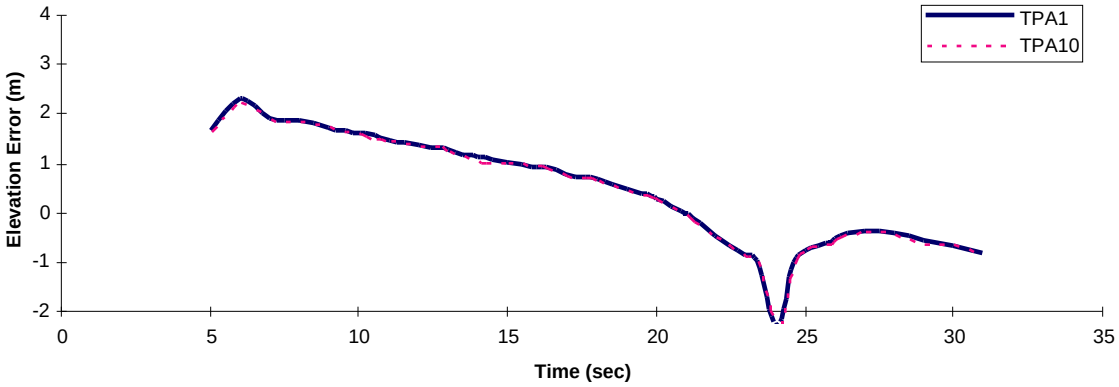


FIGURE 3.27-20. Elevation Track Errors for 300 m/s Target at 1 k/m Offset.

Figure 3.27-21 shows the combined effects of target size, range, and speed on RMS elevation tracking error. Target size has little or no effect on RMS elevation errors. Similar to the RMS azimuth errors, the RMS elevation errors decrease until target cross-over and then increase as the target range increases. The rate of decrease and increase is proportional to target speed.

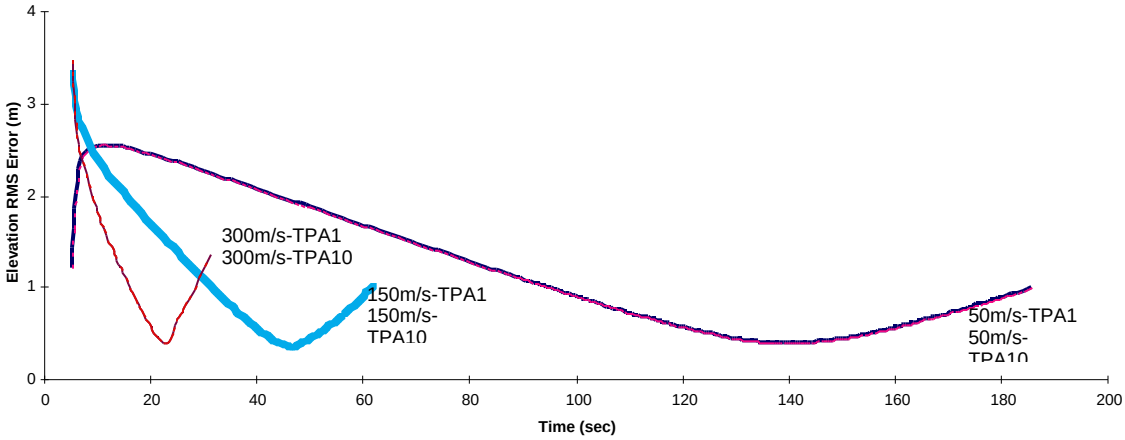


FIGURE 3.27-21. RMS Elevation Errors.

Figures 3.27-22 and 3.27-23 show the effects of tangential velocity and target size on elevation tracking. Target speed shapes the error distribution. Size has little effect. An increase in tangential velocity results in a decrease an increase in error. The distributions of errors are shown in Figures 3.27-24 through 3.27-26.

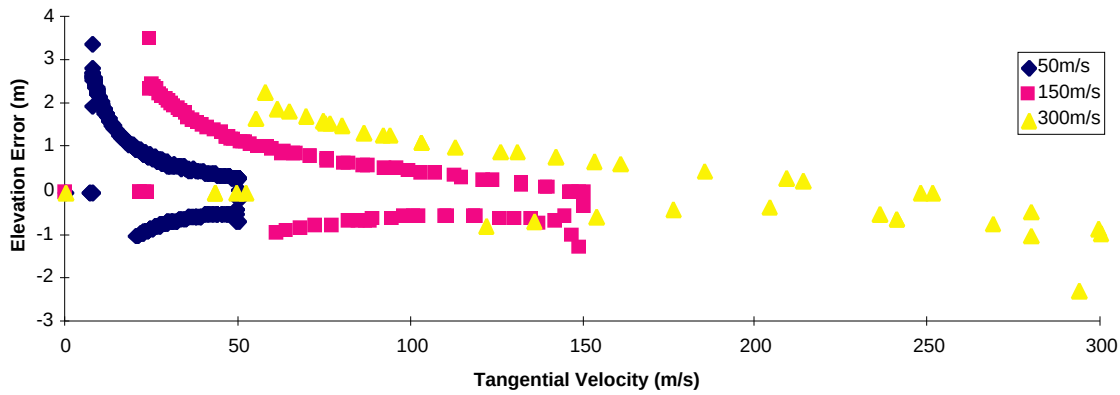


FIGURE 3.27-22. Elevation Track Errors as a Function of Tangential Velocity for TPA1.

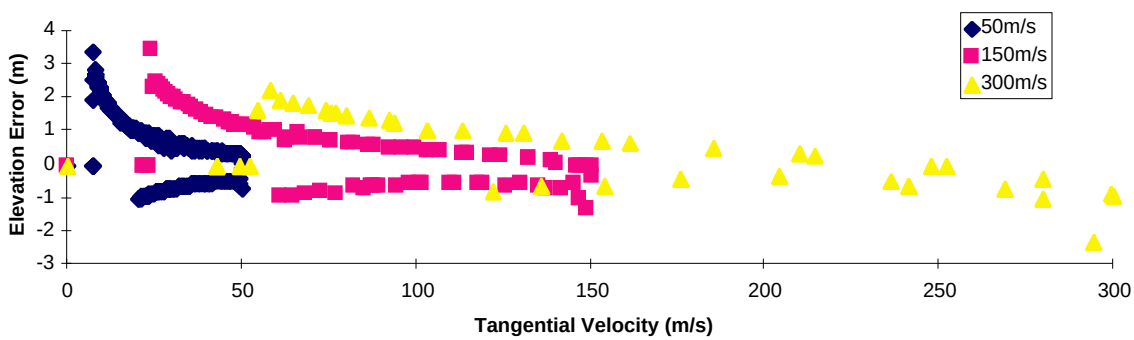


FIGURE 3.27-23. Elevation Track Errors as a Function of Tangential Velocity for TPA 10.

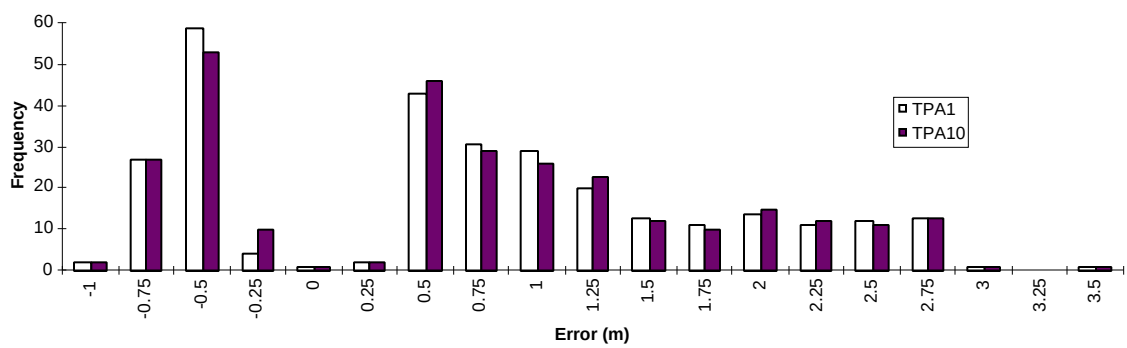


FIGURE 3.27-24. Distribution of Elevation Track Errors for 50 m/s Target.

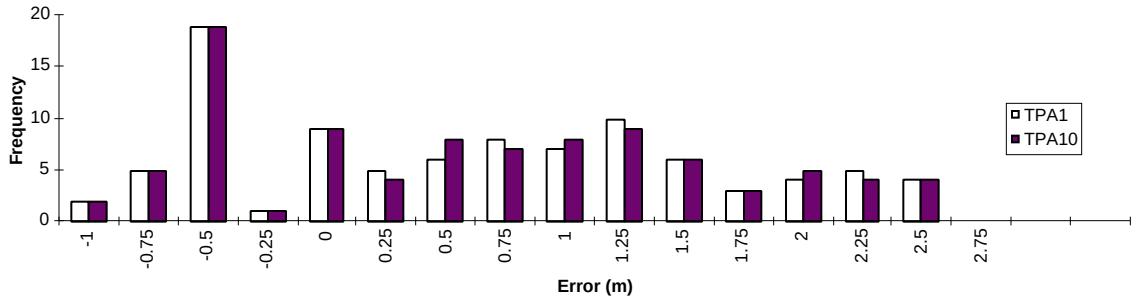


FIGURE 3.27-25. Distribution of Elevation Track Errors for 150 m/s Target.

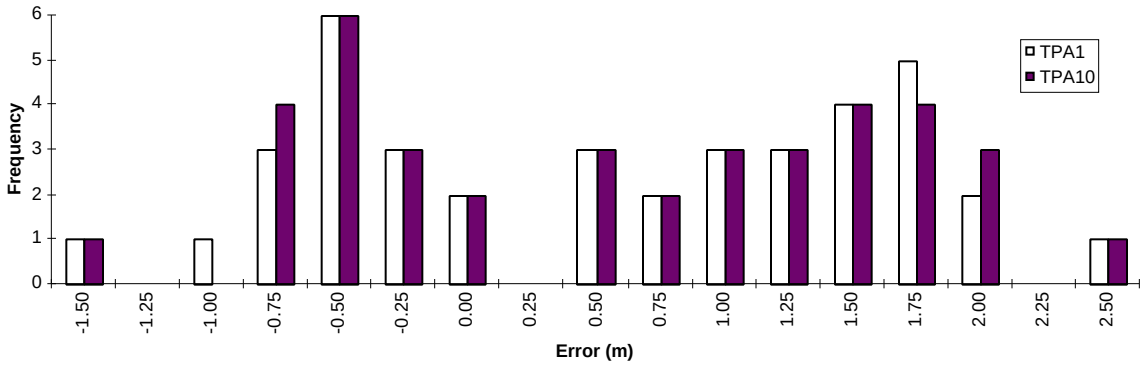


FIGURE 3.27-26. Distribution of Elevation Tracking Errors for 300 m/s Target.

Table 3.27-1 summarizes the effects of target size and speed on average and RMS azimuth errors.

TABLE 3.27-1. Azimuth Error Summary — 1000-Meter Offset.

Target Speed (m/s)	Target Size (sq m)	Average Error Magnitude (mrad)	RMS Error (mrad)	Signed Average Error (mrad)
50	1	0.469	0.492	-0.469
50	10	0.501	0.588	-0.465
150	1	0.535	0.578	-0.347
150	10	0.585	0.670	-0.346
300	1	1.385	1.753	-0.145
300	10	1.406	1.778	-0.147

Table 3.27-2 summarizes the effects of target speed and size on average and RMS elevation errors.

TABLE 3.27-2. Elevation Error Summary — Zero Offset.

Target Speed (m/s)	Target Size (sq m)	Average Error Magnitude (mrad)	RMS Error (mrad)	Signed Average Error (mrad)
50	1	0.518	1.556	-0.401
50	10	0.515	1.555	-0.400
150	1	1.081	2.709	-0.735
150	10	1.080	2.710	-0.734
300	1	1.620	4.878	-1.120
300	10	1.630	4.889	-1.113

3.27.3 Conclusions

Both target speed and size affect the angle track function of *RADGUNS*. For both azimuth and elevation, the tracking errors increase as target speed increases. An increase in target size causes an increase in azimuth error. This effect decreases as target speed increases. Target size does not significantly affect elevation errors.