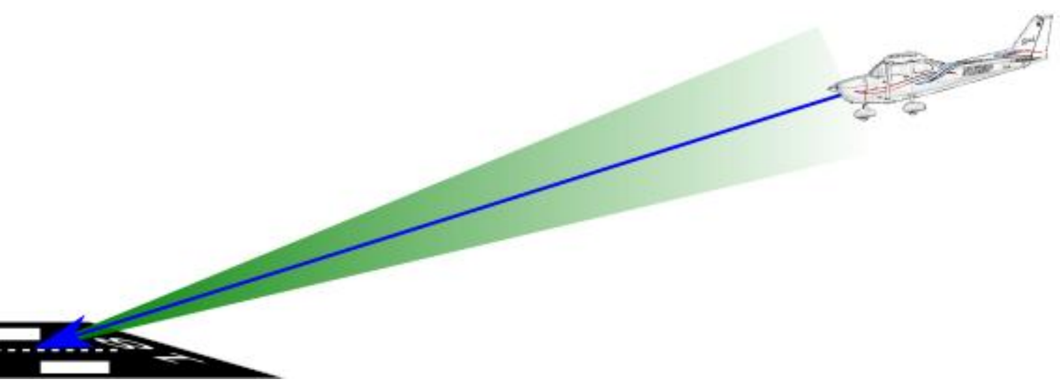
GLIDE SLOPE CONTROL SYSTEM

Prepared
by



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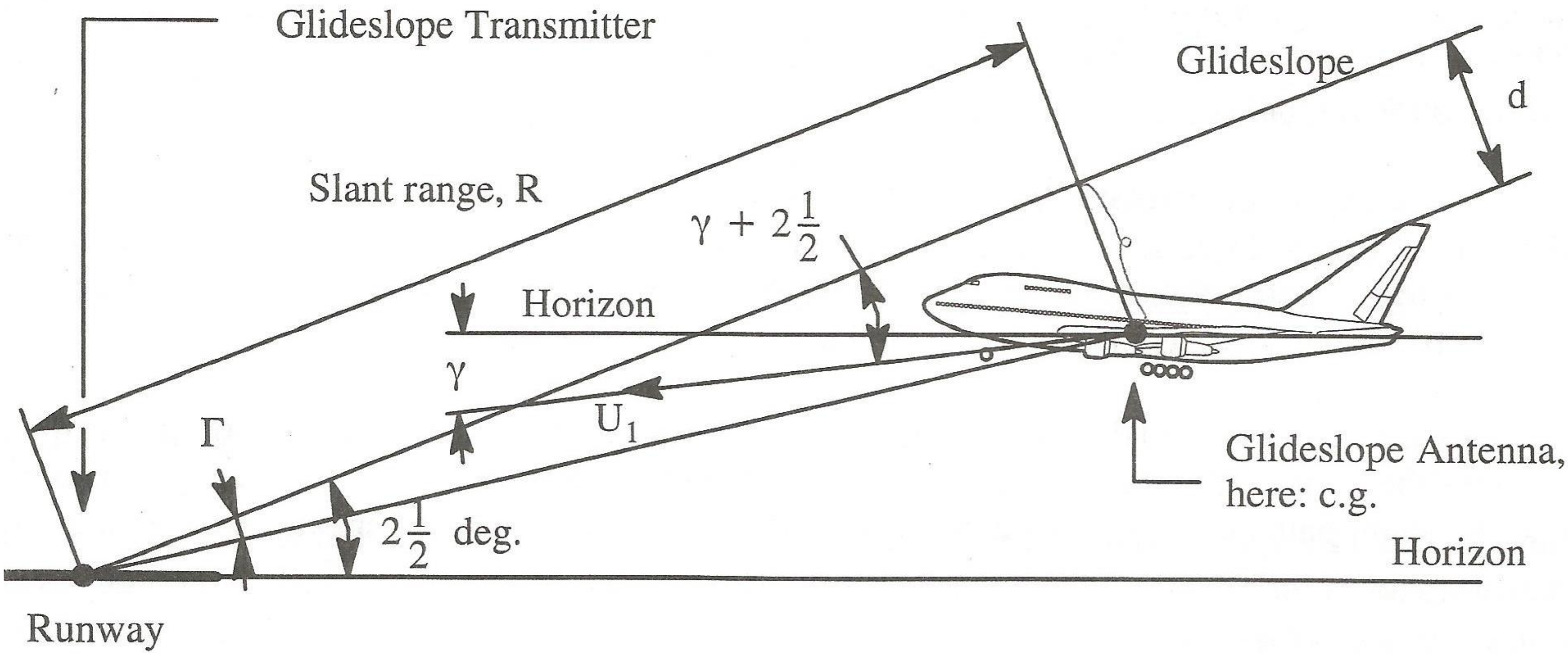
Note: γ as shown is negative.



- It is assumed that the airplane already has a pitch attitude command control system as well as speed control system.
- The pitch attitude command system control the short period damping.
- Speed control system controls the phugoid damping.
- The another important aspect of speed control system is to maintain the flight path angle of the aircraft during approach.

- Several aspect of the figure must be explained
  - the airplane glide slope antenna is assumed to be coincide with the center of gravity.
  - the C.G is supposed to be driven along the glide slope.
  - The glide slope error angle l is sensed by a glide slope receiver mounted on board the airplane.
  - The aircraft pitch attitude command system is used to keep the airplane on the glide slope.
  - Some form of speed control (auto throttle or auto drag) assumed to be exist.

- The velocity with which the airplane approaches the glide slope under the control of pitch attitude command system is

$$\dot{d} = U_1 \sin(\gamma + 2.5) \approx U_1 \frac{\gamma + 2.5}{57.3}$$

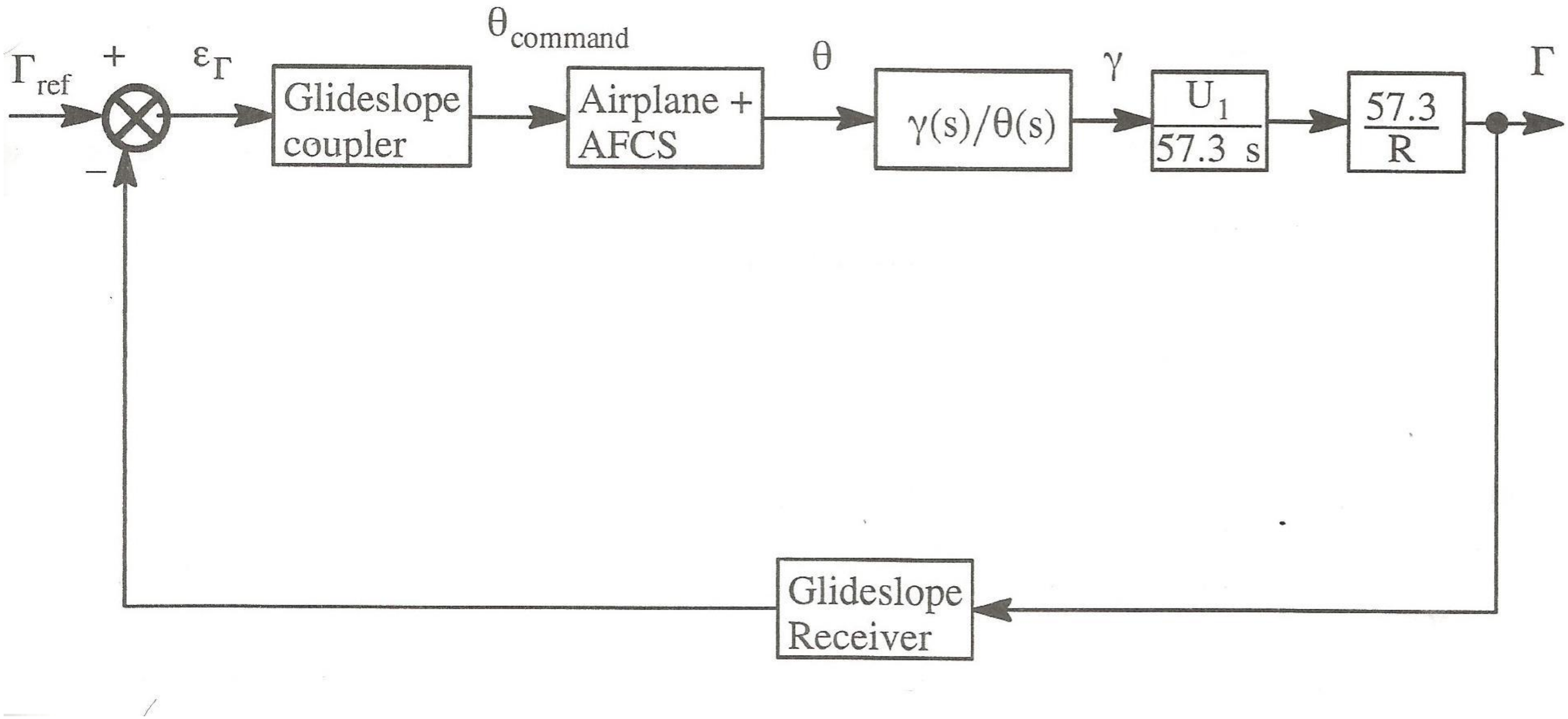
The distance d from the c.g (glide slope antenna) to the glideslope is found by inetgration of above equation

$$d = \int U_1 \frac{\gamma + 2.5}{57.3} dt$$

$$\textit{In the } s-\textit{domain} \quad d(s) \approx \frac{U1}{57.3s} L(\gamma + 2.5)$$

The relationship between glide slope errorangle Γ, d *and slantrange* R *is*

$$\Gamma \approx \frac{d}{R}$$



Functional Block diagram of a Glide slope hold mode

- The changes in the flight path angle causes a change in the glide slope error angle which is sensed by the glide slope receiver and fed back to the coupler.

- The bandwidth of the glide slope receiver is considered very large relative to that of the other blocks in the system. The glide slope receiver will therefore be consider as pure gain.

- The coupler transfer function usually takes the form of ‘proportional plus” network with the following transfer function.

$$TFF_{coupler} = K_c\left(1+\frac{0.1}{s}\right)$$

$$K_c - Coupler\ Gain$$

0.1 *is the weighting constant.*

- The purpose of the weighting integrator in the coupling transfer function is to allow the system to cope with turbulence while on the glide slope.

$$\frac{\theta(s)}{\theta_{command}(s)} = \frac{910.2s^2 + 446.4s + 30.97}{228.5s^5 + 4787s^4 + 6307s^3 + 4648s^2 + 633s + 107.3}$$

$$\frac{\gamma(s)}{\theta(s)} = \frac{6.555s^3 - 2.4s^2 - 42.5s + 0.296}{-91.01s^2 + 44.6s - 3.097}$$

- There are two potential problems with the glide slope hold loops as shown in figure.
- The first one is the appearance of two s=0 poles.
- Second one is the slant range R becomes smaller as the aircraft approaches runway.
- As the slant range decreases the effective loop gain becomes very large. To guard against the two poles at the origin going unstable too soon. Some form of distance measurement technique (DME) is often required to adjust the coupler gain as the aircraft approaches closer to the runway.
- Figure.1 shows the glide slope root locus for the case of R=5nm(30380feet). This figure shows the open loop system poles and zeros.

- Figure.2 shows the root locus for R=1nm=6076ft. Note the shift of the operating point at the right. Note that the system is now neutrally stable at the same coupler gain.

- Figure.3 shows the root locus for R=0.1nm=608ft. Because the glide slope transmitting antenna is located at a relatively short distance from the runway threshold the latter case represents situation where the airplane should be starting its flare maneuver. Clearly the system is unstable at this point.

- One way to solve the problem is to adjust the coupler gain downwards as the distance to the glide slope transmitter decreases(by using DME).

- In older autopilots the coupler gain is adjusted downwards as a result of clock which starts when the airplane is over the outer marker.

- Another way is to ass some form of compensator to the system

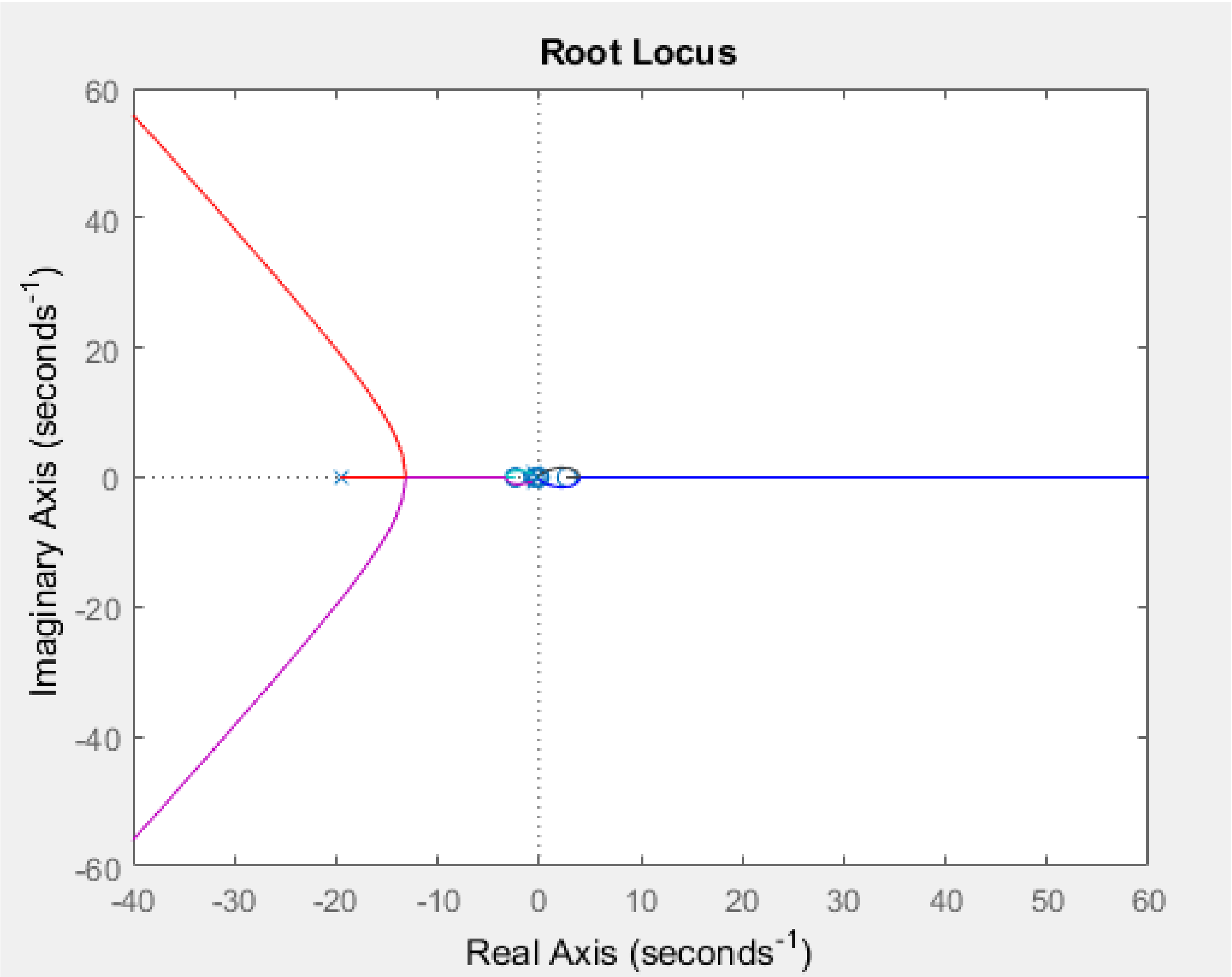
- Figure.4 shows what happens at 5nm slant range if a 10*(s+0.3)/(s+3) compensator is added to the coupler transfer function.

- Note the favorable effect this has on the critical branch on root locus.

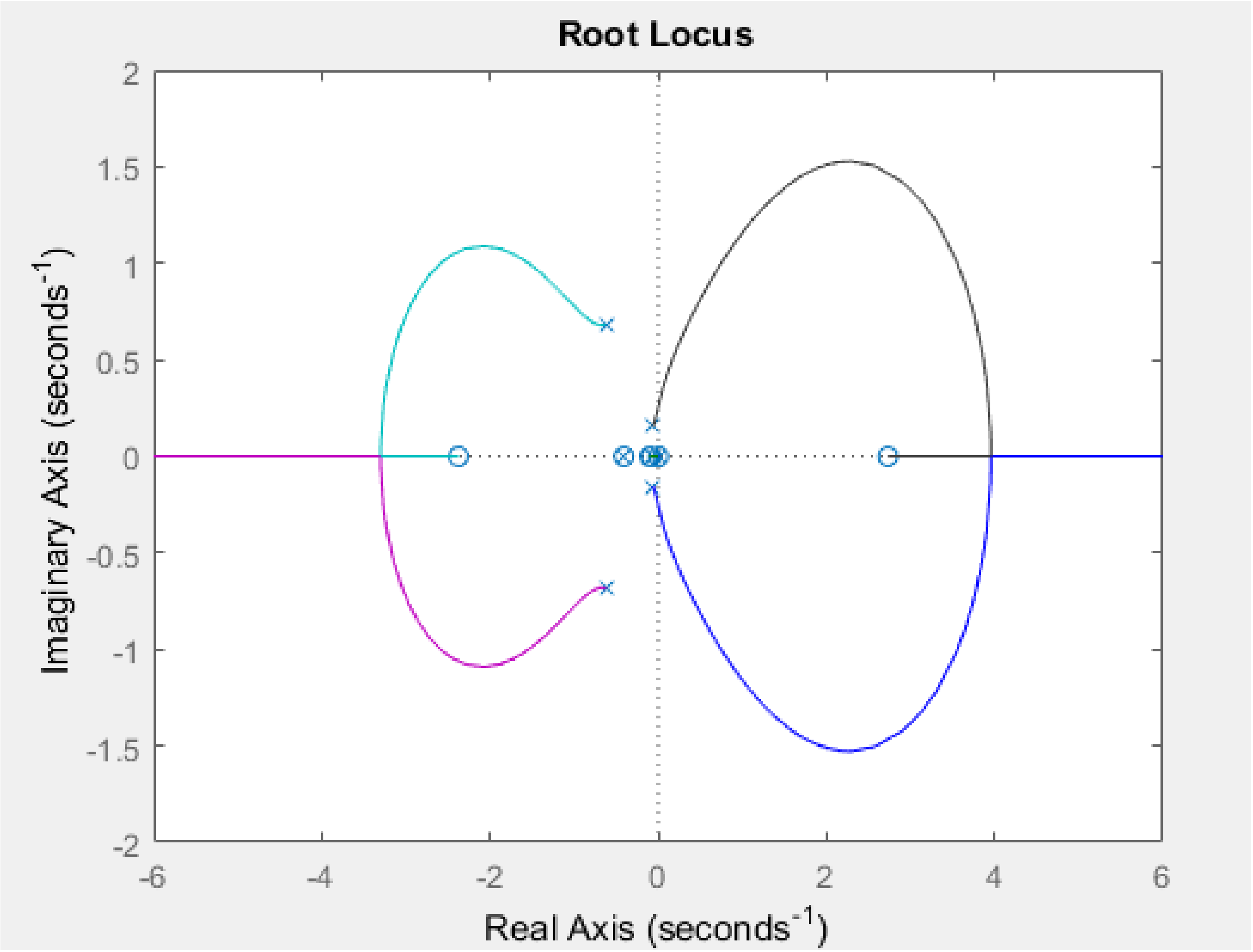
- Most autopilots with glide slope capability have what Is referred as “glide slope intercept and hold feature” what has been discussed here is only the “hold” part. Figure.5 shows the typical flight path which would arise if the autopilot is put in intercept and hold mode.

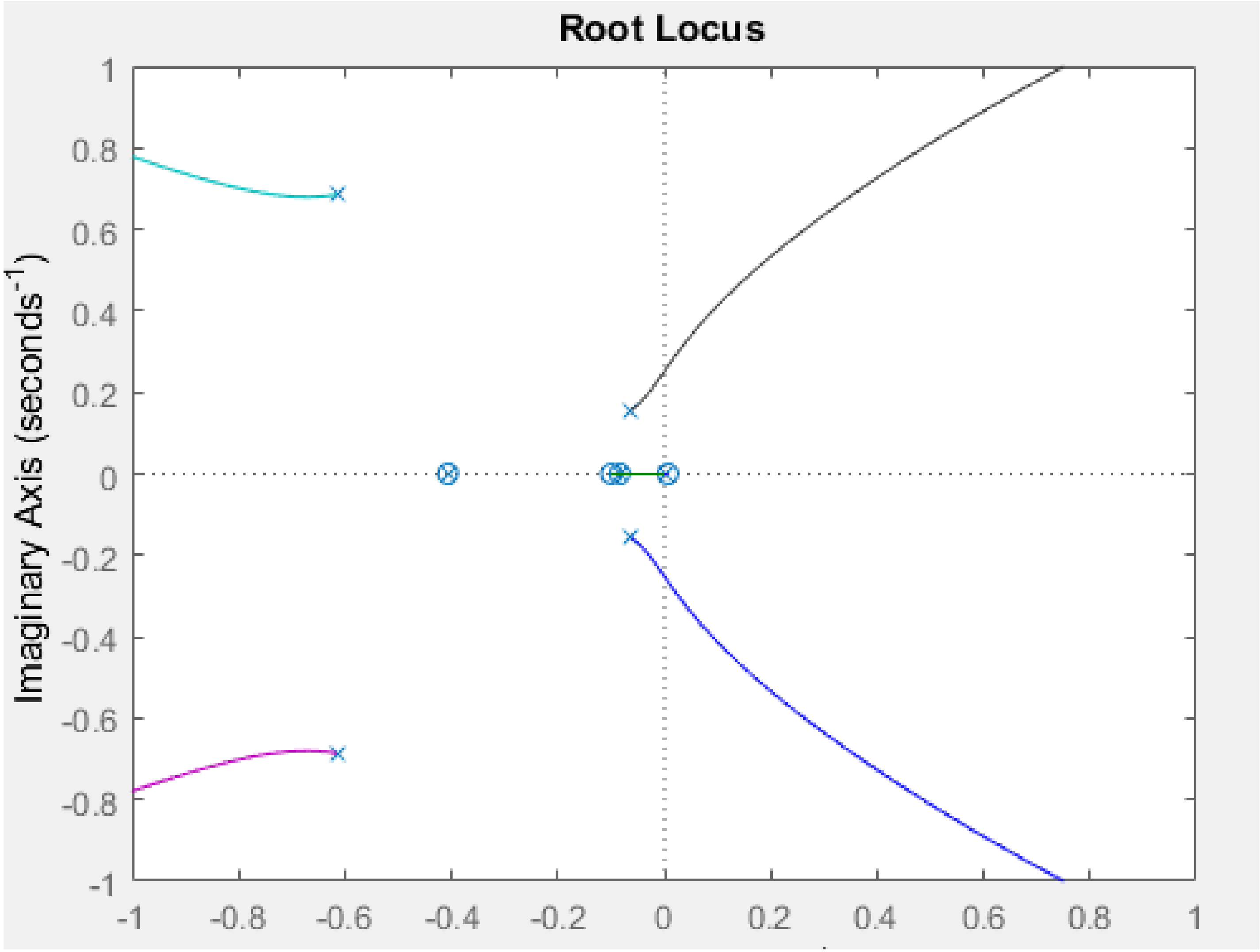
- At the intercept point P the autopilot would use it full authority to “nose the airplane down” depending on the authority limit designed into autopilot this could result in very unacceptable g excursions, therefore every intercept mode has a smoothing feature built in which limits the g excursions.

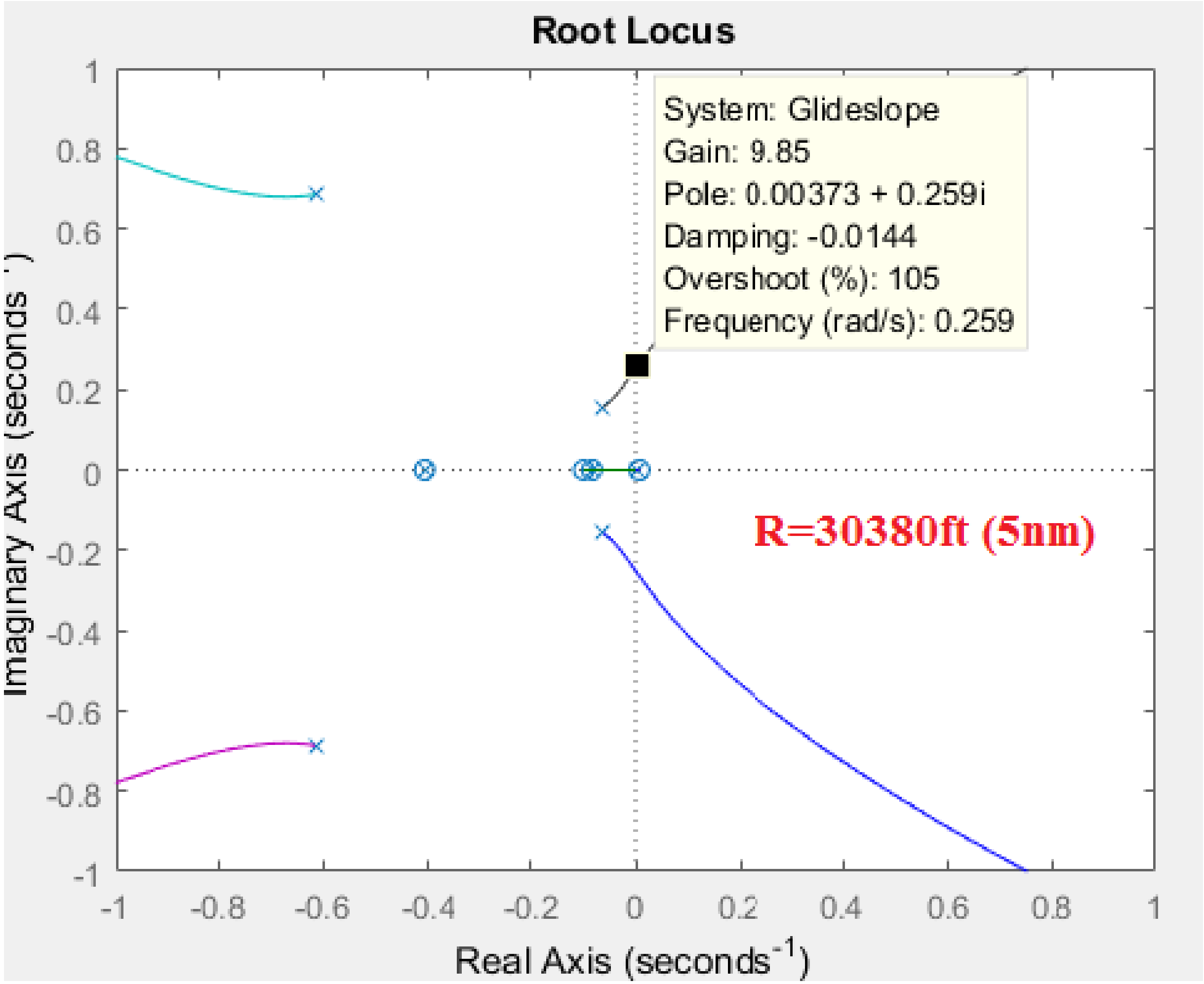
- Finally time domain analysis has been conducted in the presence of turbulences and performance has been evaluated.



Root Locus
60
40
20
0
-20
-40
-60
Imaginary Axis (seconds^{-1})
-40
-30
-20
-10
0
10
20
30
40
50
60
Real Axis (seconds^{-1})

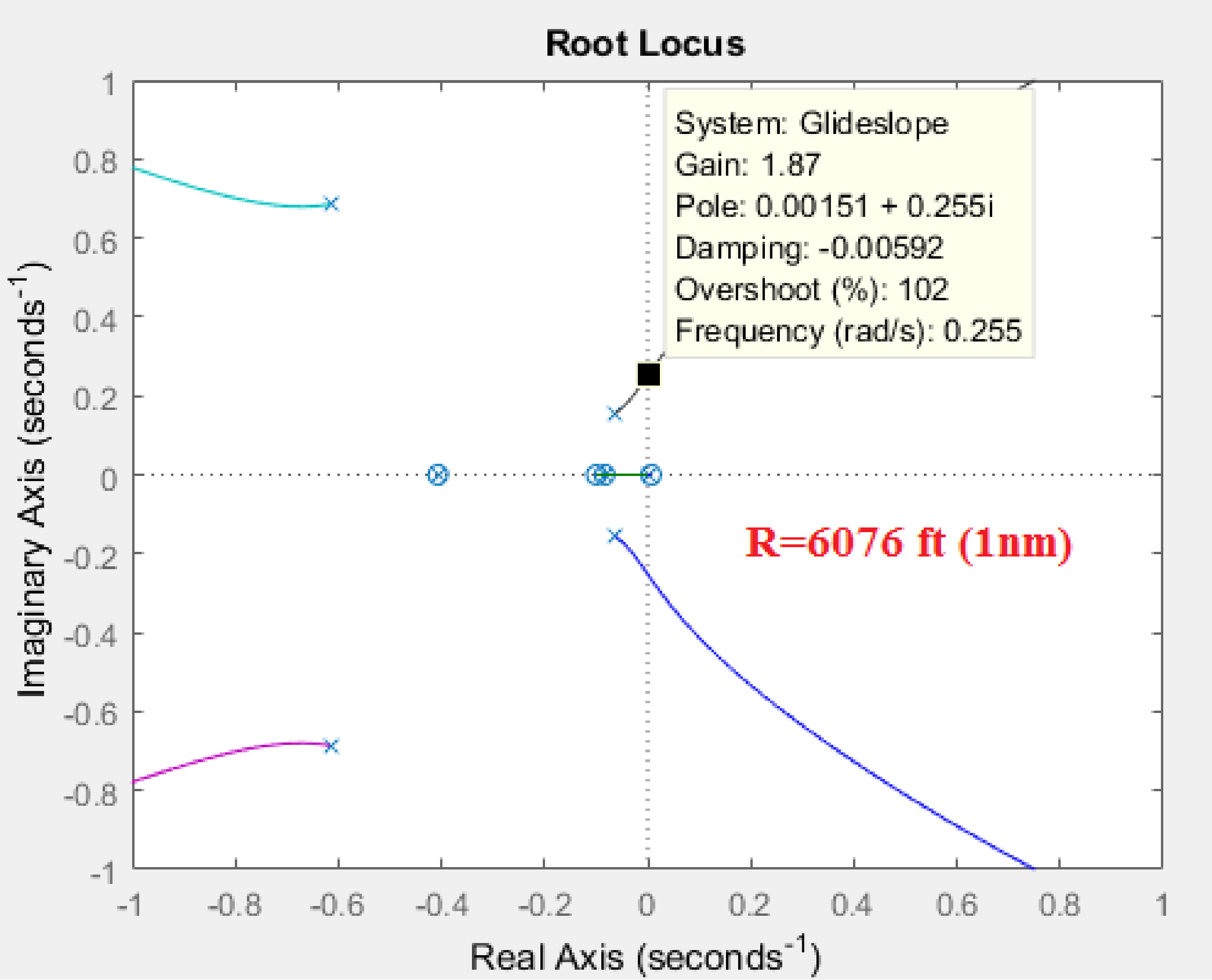

Root Locus
Imaginary Axis (seconds⁻¹)
Real Axis (seconds⁻¹)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-6
-4
-2
0
2
4
6


Root Locus
Imaginary Axis (seconds^{-1})
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1



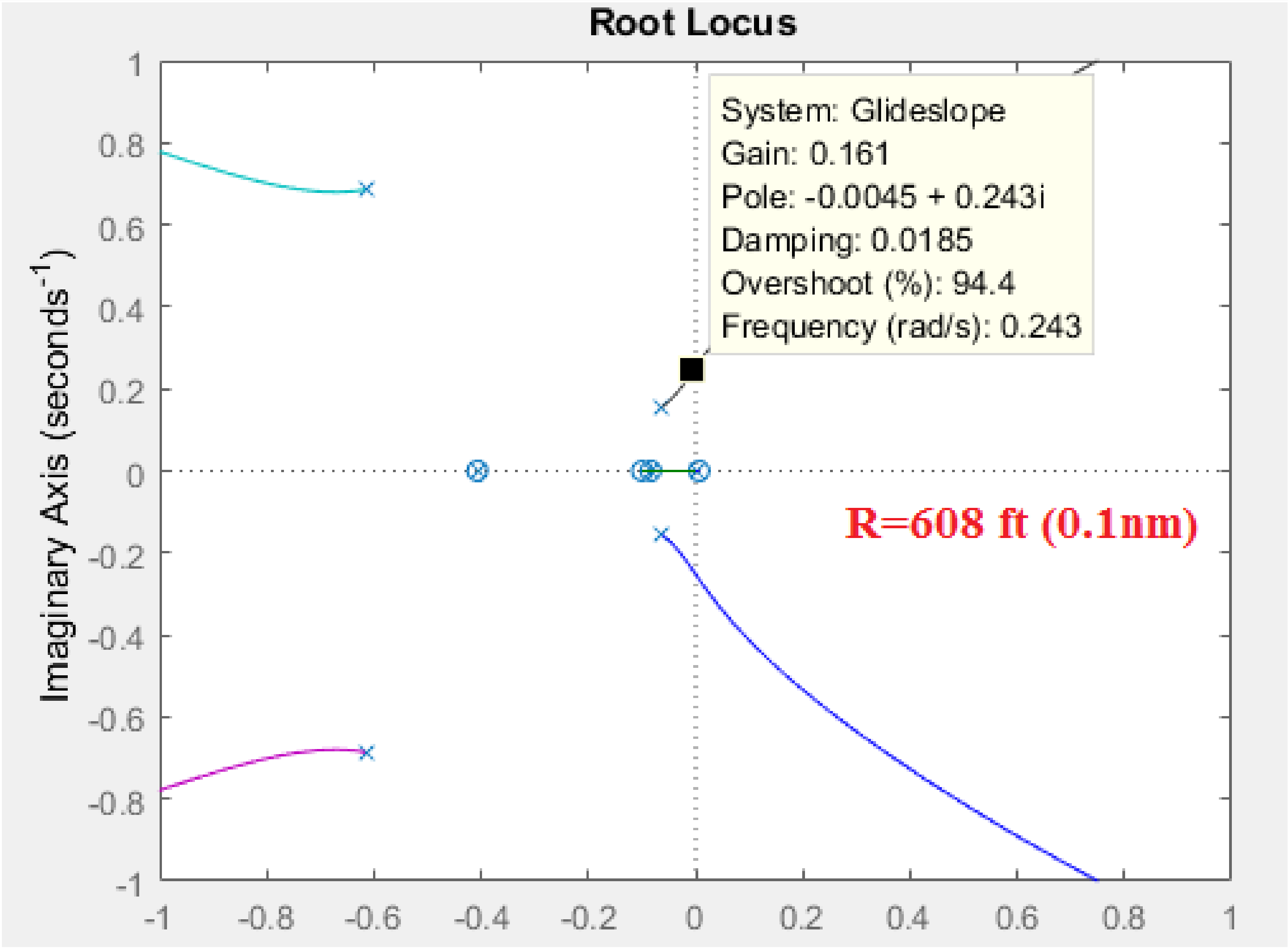
Root Locus
System: Glideslope
Gain: 9.85
Pole: 0.00373 + 0.259i
Damping: -0.0144
Overshoot (%): 105
Frequency (rad/s): 0.259
R=30380ft (5nm)
Imaginary Axis (seconds⁻¹)
Real Axis (seconds⁻¹)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Figure 1



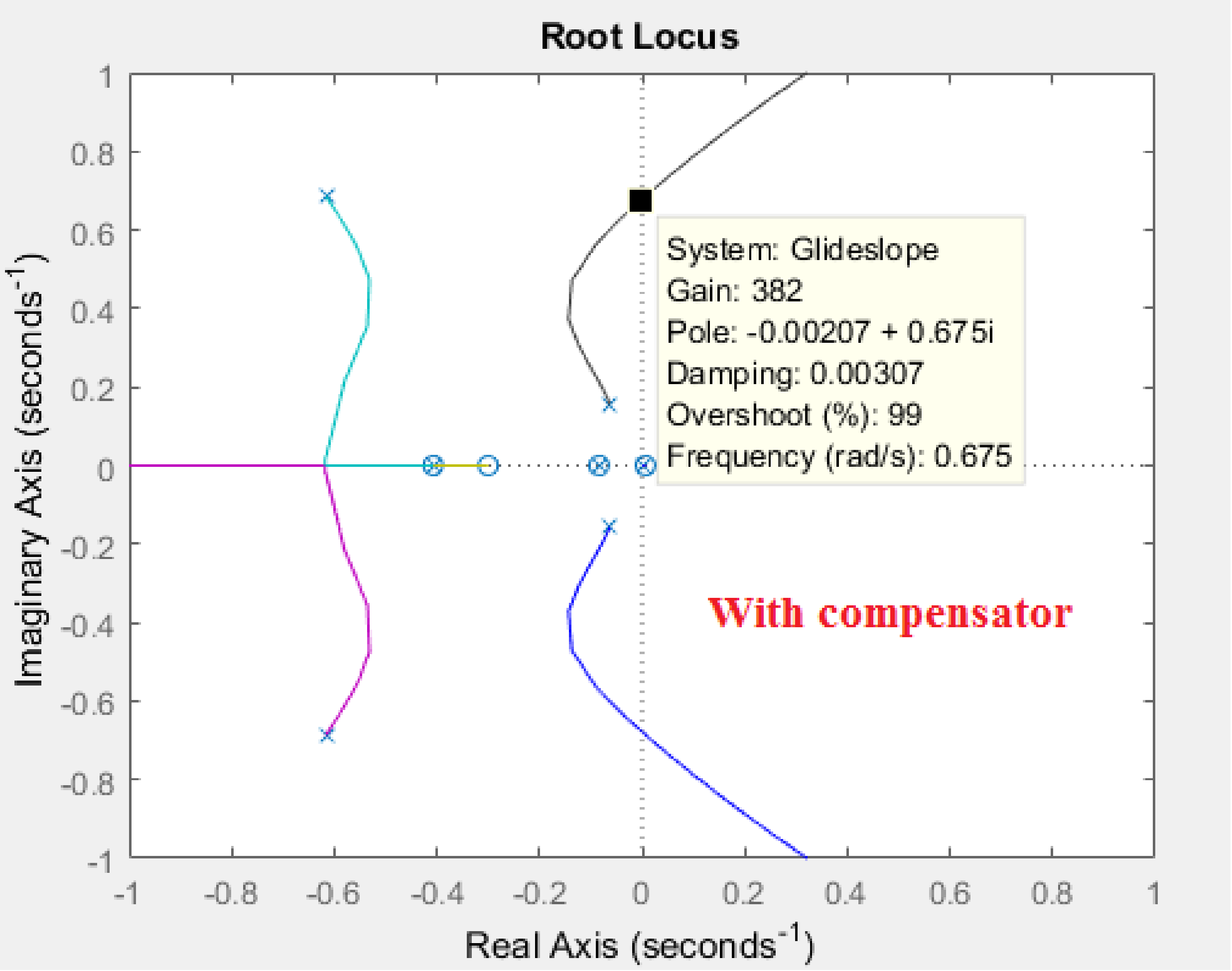
Root Locus
System: Glideslope
Gain: 1.87
Pole: 0.00151 + 0.255i
Damping: -0.00592
Overshoot (%): 102
Frequency (rad/s): 0.255
R=6076 ft (1nm)
Imaginary Axis (seconds^-1)
Real Axis (seconds^-1)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

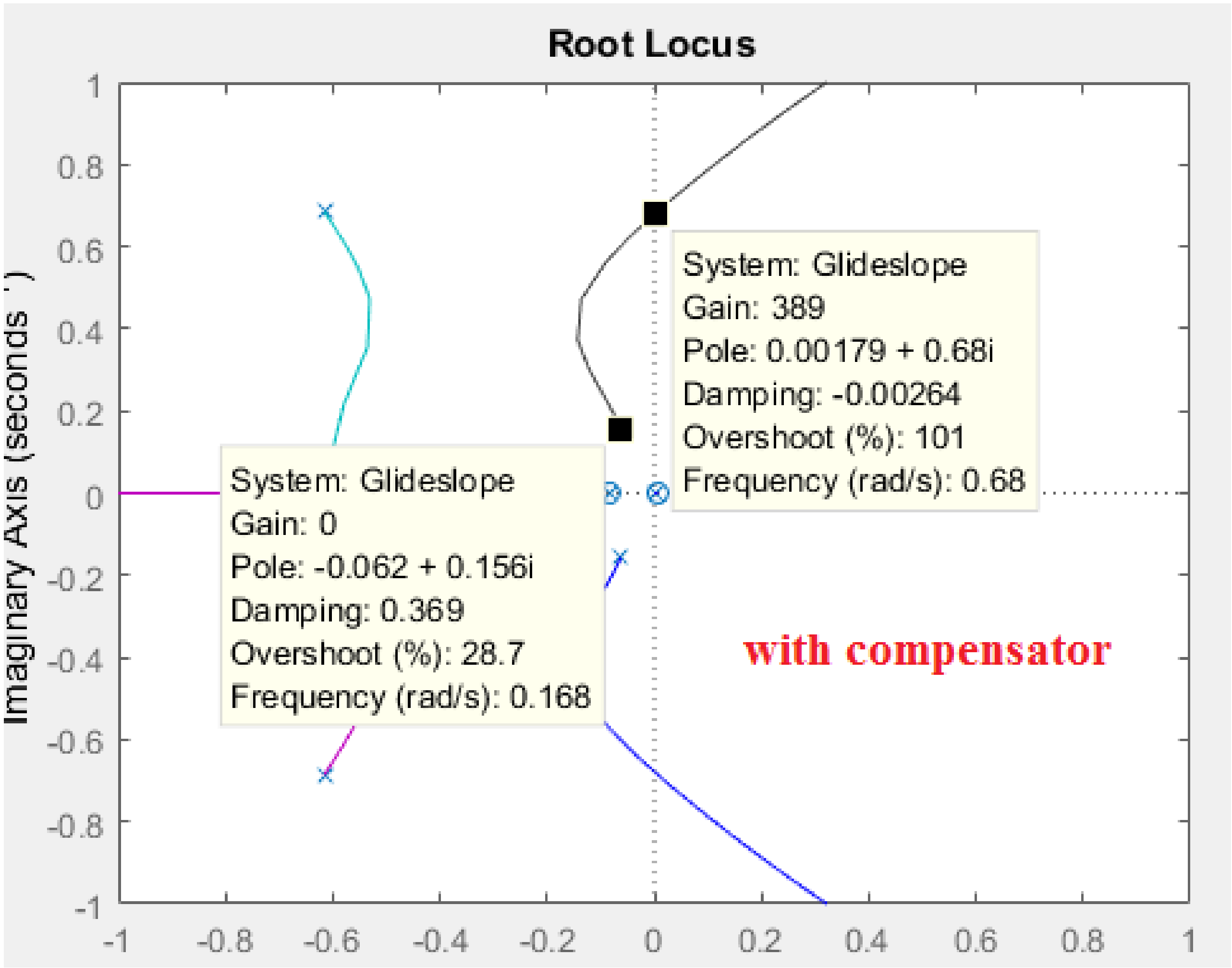
Figure 2



Root Locus
System: Glideslope
Gain: 0.161
Pole: -0.0045 + 0.243i
Damping: 0.0185
Overshoot (%): 94.4
Frequency (rad/s): 0.243
R=608 ft (0.1nm)
Imaginary Axis (seconds⁻¹)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Figure.3


Root Locus
System: Glideslope
Gain: 382
Pole: -0.00207 + 0.675i
Damping: 0.00307
Overshoot (%): 99
Frequency (rad/s): 0.675
With compensator
Imaginary Axis (seconds-1)
Real Axis (seconds-1)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1


Root Locus
Imaginary Axis (seconds⁻¹)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
System: Glideslope
Gain: 389
Pole: 0.00179 + 0.68i
Damping: -0.00264
Overshoot (%): 101
Frequency (rad/s): 0.68
System: Glideslope
Gain: 0
Pole: -0.062 + 0.156i
Damping: 0.369
Overshoot (%): 28.7
Frequency (rad/s): 0.168
with compensator

THANK YOU