Instrument package

Sensor: Star Tracker

Actuator: Gas Jets (*)
Reaction Wheels
Magnetic Torquer

Specifications:
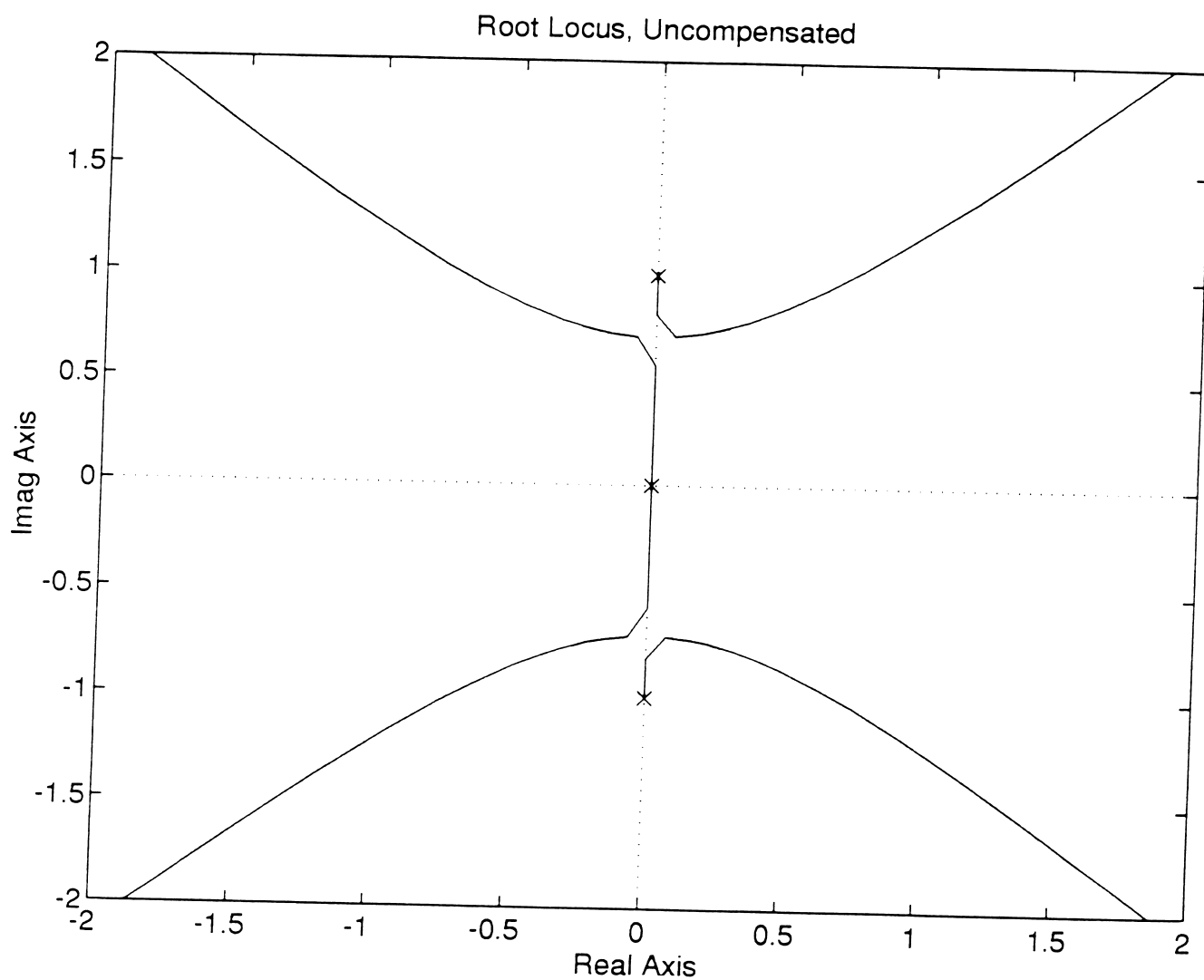
settling time ~ 10 sec.
reasonable overshoot

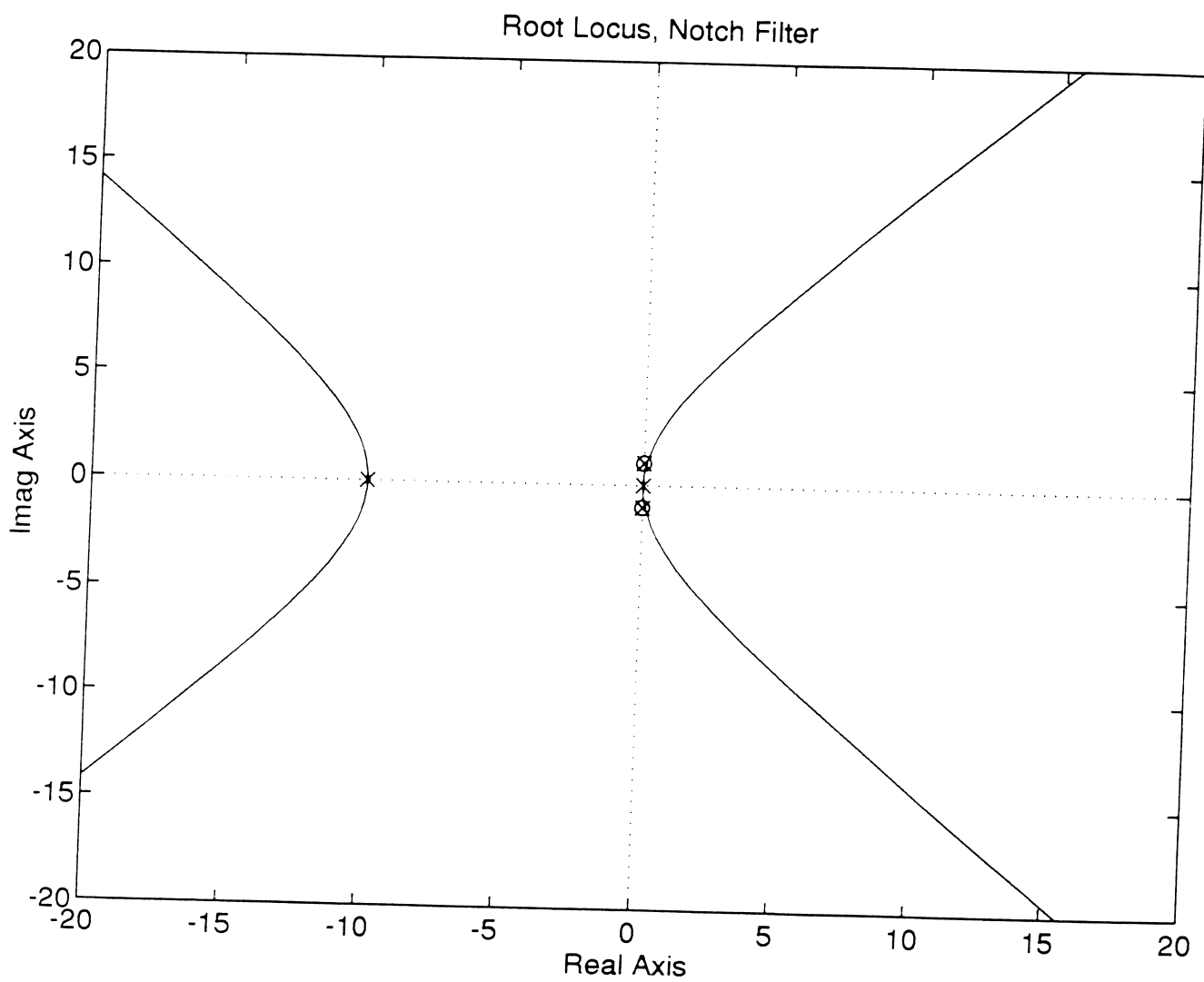Linear Model:

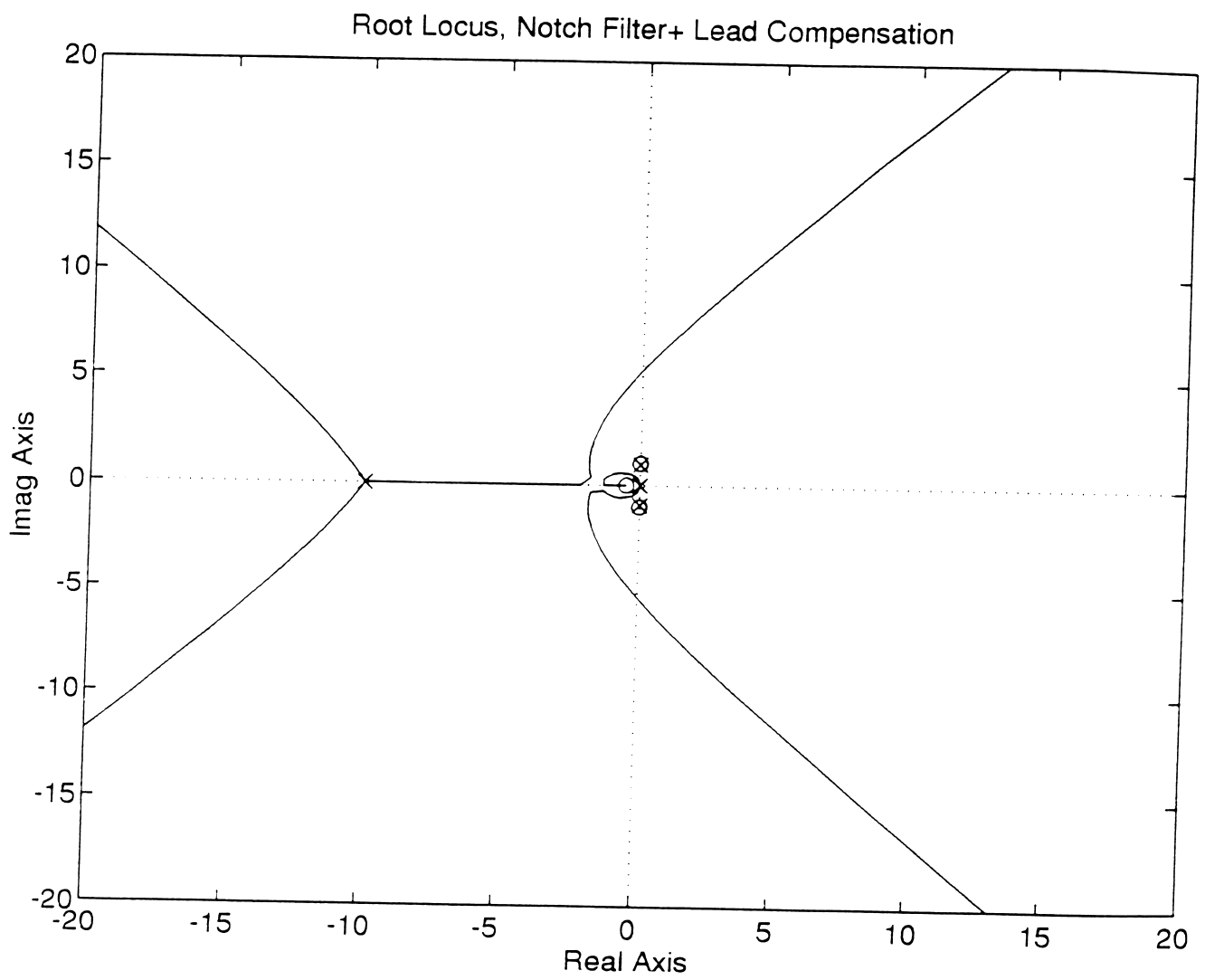$$\frac{\theta_2}{T} = G(s) = \frac{bs + k}{\left(J_1 J_2 s^2 + (bs+k)(J_1 + J_2)\right) s^2}$$

Take $b \cong 0$
$J_1 = J_2 = 1$
$k = 1$
(nominal)

$$G(s) = \frac{1}{s^2 (s^2 + 1)}$$

rigid body mode
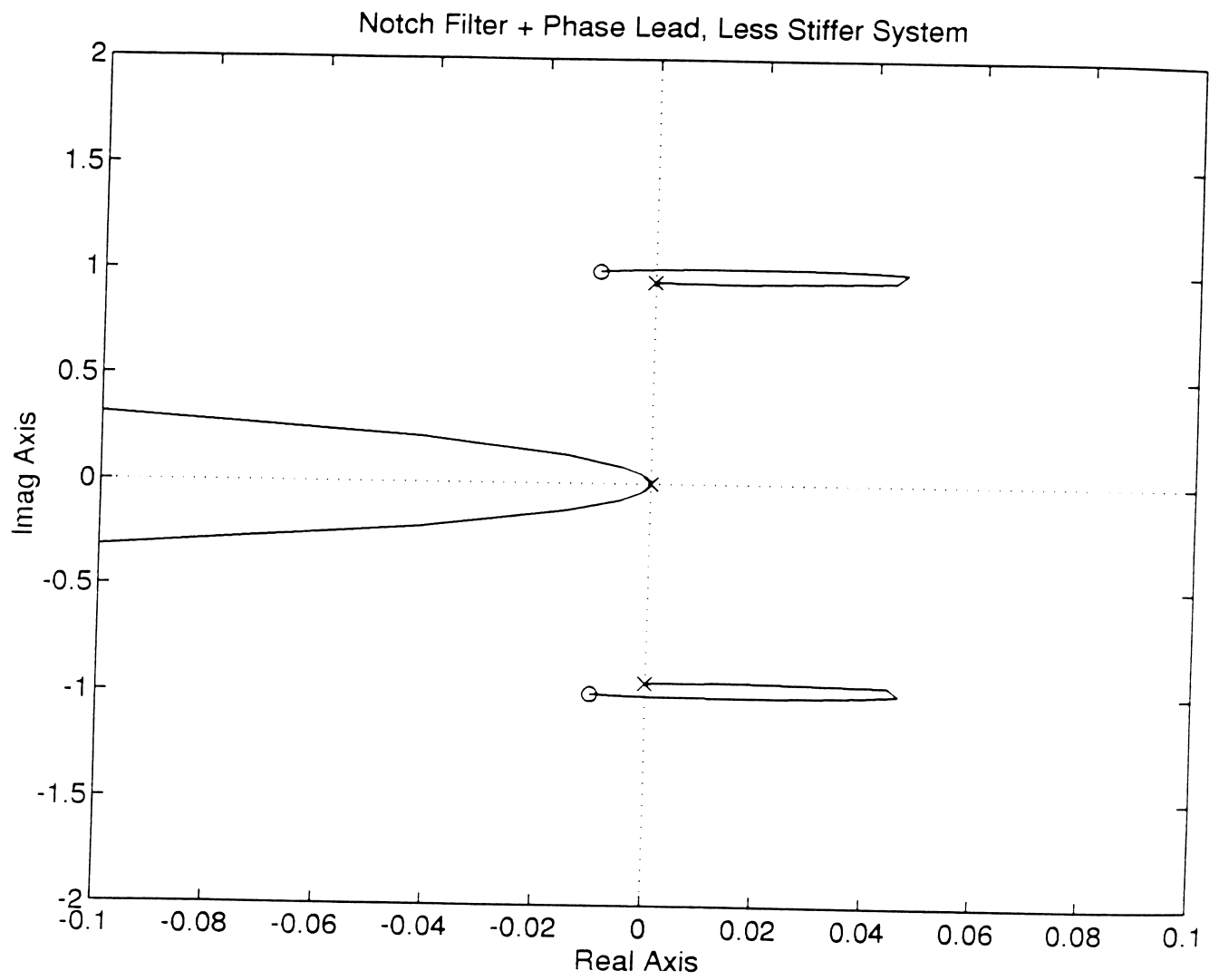
flexible body mode

Root Locus, Uncompensated

Root Locus, Notch Filter

Root Locus, Notch Filter+ Lead Compensation

Notch Filter + Lead Compensation

Notch Filter + Phase Lead, Less Stiffer System

Notch Filter + Phase Lead, Less Stiffer System

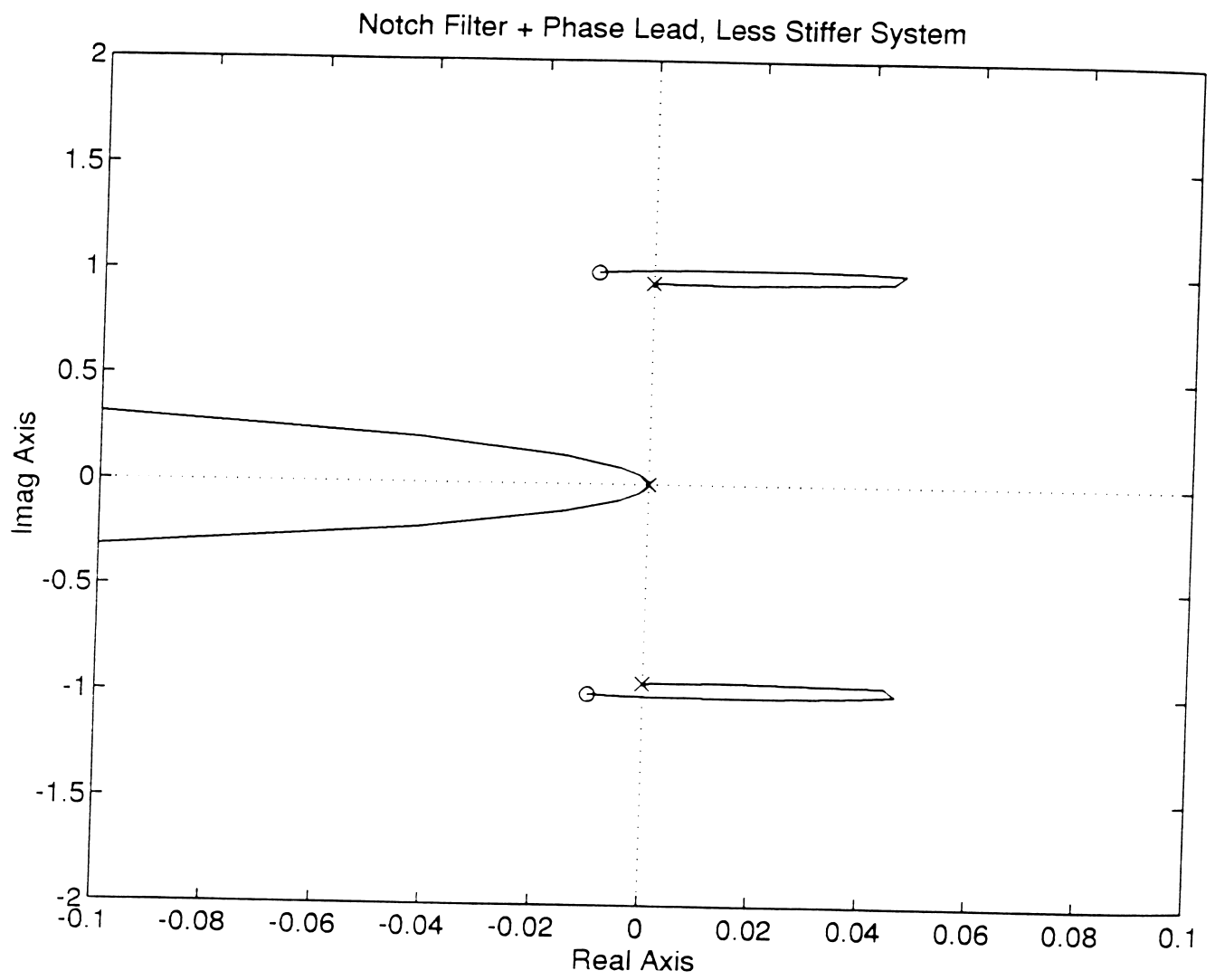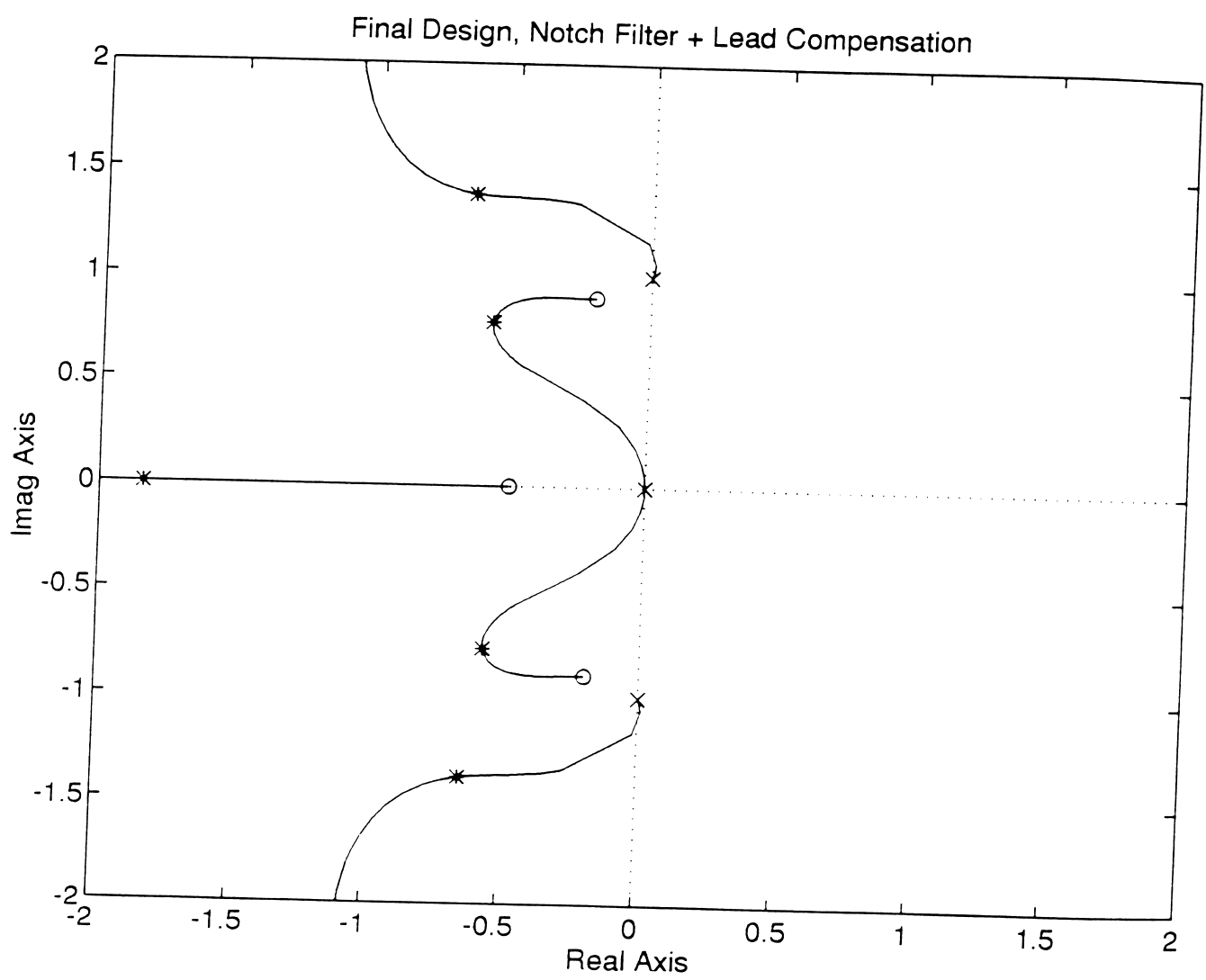Final Design, Notch Filter + Lead Compensation

SZNAIER

Since we have 2 poles on the $j\omega$ axis, we could try to "notch" these frequencies out using a notch filter

An ideal notch will be $G_3 = \dfrac{s^2 + 1}{(s + 10)^2}$

However this will produce a pole-zero cancellation on the axis (undesirable! why?)

$\Rightarrow$ Try $G_3(s) = \dfrac{(s + 0.01)^2 + 1}{(0.1s + 1)^2}$ $\quad$ (zeros at $s = -0.01 \pm j$)
$\quad$ poles at $s = -10$

The new Root Locus looks better, but still needs to be pulled towards the left $\Rightarrow$ add another phase lead stage

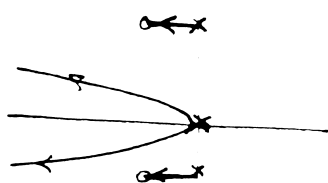Say $G_2 = \dfrac{s + 0.5}{(0.1s + 1)}$ $\quad \Rightarrow$ Total compensator so far:

$$G_c = G_1(s)G_2(s) = K\dfrac{(s + 0.5)\left[(s + 0.01)^2 + 1\right]}{(0.1s + 1)^3}$$

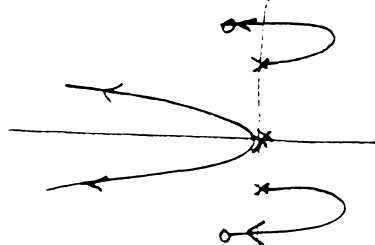where we can adjust K to try to meet the specifications.

Note that this still yields roots very close to the $j\omega$-axis $\Rightarrow$ poor damping, large settling time, large overshoot.

A more serious problem : If the frequency of the poles of the plant moves (i.e. if we have a less stiff plant) we could go unstable

Nominal plant

stable for all k

plant with $k <$ nominal (or $J >$ nominal)

unstable for almost all k

This can be taken care of by moving the zeros of the compensator away from the axis and towards lower frequencies (closer to 0)

$\Rightarrow$ Try $G_c = K\dfrac{(s + 0.5)\left[(s + 0.2)^2 + 0.9487\right]}{(0.1s + 7)^3}$