Design Project Assignment–8 (Due date: Thu, Nov 30, 2006)

1. Our final part of the project involves the design of a controller that enables the system to track any constant commanded deviation from the runway centerline, $\Gamma_{ref}(t)$. Once we can do this, we can make the system track the command $\Gamma_{ref}(t) = 0$ which will align the aircraft with the runway centerline.

We start by finding a transfer function from the heading angle ψ to the deviation from the runway centerline $\Gamma(t)$. Note from the equation (3) in Assignment 7 that

$$D(s) = \frac{1}{s}\psi(s) \tag{1}$$

We now need to use equation (2) to find a transfer function from d to Γ. However, this is not straight forward since $R(t)$ changes with time. For example, at $t = 0$, the aircraft is at an initial range $R_0 = 15000m$,and thus

$$\Gamma(t) = \frac{d(t)}{15000}, \tag{2}$$

but at $t = 200s$ with the aircraft travelling at $U_0 = 67m/s$,

$$\Gamma(t) = \frac{d(t)}{1600}. \tag{3}$$

To circumvent this problem, we will design our compensator for a nominal value of the range $\bar{R} = 7000m$. Thus, we assume that

$$\Gamma(t) = \frac{d(t)}{\bar{R}} = \frac{d(t)}{7000}, \tag{4}$$

and from (1), it follows that

$$G_{\Gamma\psi(s)} = \frac{\Gamma(t)}{\psi(s))} = \frac{U_0}{7000s}. \tag{5}$$

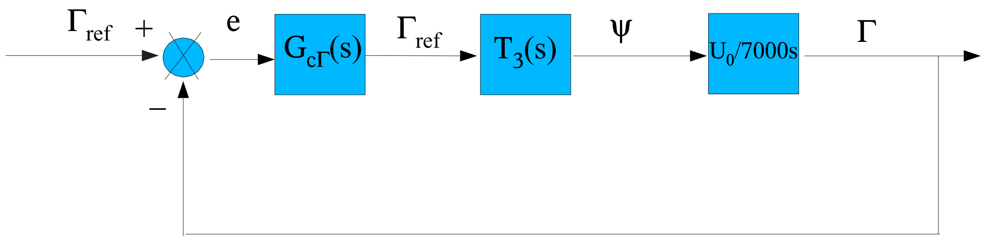

Figure 1: Block Diagram for Heading Angle Tracking

The block diagram of the closed-loop system using this approximate relation for Γ is shown in Fig. 1 where $T_3(s)$ is the closed-loop transfer function shown in Figure 1 of Assignment 7. The design will be performed using the transfer function in 5 but we will require sufficient gain margin to maintain stability as the gain of $G_{\Gamma\psi(s)}$ changes from 67/15000 at $t = 0$ to 67/1600 at $t = 200s$.

From the block diagram, we note that the transfer function $G_{\Gamma\psi(s)}$ has an integrator in it, and by the internal model principle, we are guaranteed aysmptotic tracking of step commands if the $G_{c\Gamma(s)}$ is designed such that the closed-loop is asymptotically stable. To obtain the satisfactory transient response and gain margin, use the root-locus design tool *"rltool"* in MATLAB to design a compensator to satisfy the following specifications:

(i) Gain margin $G_m > 15$

$$G_m = \frac{Gain\ at\ imaginary\ crossing}{Design\ value\ of\ gain}$$

(ii) Rise time $t_r < 60s$.

(iii) Settling time $t_s < 130s$.

To use the root-locus design tool *"rltool"* in MATLAB first calculate the open-loop transfer function from the Fig. 1 which will be

$$T(s) = T_3(s) * \frac{U_0}{7000s}$$

then define T in MATLAB using *tf* command and then write

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>> rltool(T)
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After writing this command root-locus design tool *"rltool"* window will pop-up and you will see the root-locus of your system. Using this tool you can change your gain to evaluate the stability of the system and also using the shortcut buttons on the left side you can add poles and zeros to change the root-locus of the system and increase the gain margin. You can also use this tool to see the step response of the system using the *Response to Step Command* under *Analysis* section but to see the correct step response of the system and evaluate the given specifications you should run your simulink model because of the fact that you don't consider the initial conditions while using the *"rltool"*.

2. (SIMULINK)

(i) Include the compensator $G_{c\Gamma(s)}$ obtained from section (1) in your SIMULINK block diagram. Use the constant input block from the *Sources* block library to command a reference of $\Gamma_{ref}(t) = 0$. Now feedback $\Gamma(t)$ from the blocks that you included in Assignment 7 and close the loop. (Do not use the transfer function $G_{\Gamma\psi(s)}$ to obtain Γ from ψ.) Include *To Workspace* blocks to dump d, Γ and the range τ to the workspace in addition to all the other variables from Assignments 6 and 7. Ensure that the variable names are all lower case to make them compatible with the animation code. Set the initial condition on ψ to $12°$ in the block that integrates $\dot{\psi}$, the initial condition on $d = -2000m$ in tne integrator block that integrates $\dot{d}$, and the initial range to $R_0 = 15000m$ in the range subsystem. Simulate the system for 200 seconds and plot $\phi(t), \psi(t)$, d(t) and $\Gamma(t)$ versus time t.

(ii) Copy and run the animation code *"animation_final.m"* from ASSIGNMENTS folder. Two windows will pop up. Move them until you can view both figure windows and your MATLAB window clearly and hit return at your MATLAB command prompt. One figure shows the aircraft heading and roll attitude. The other figure tracks the trajectory of the aircraft with respect to the runway centerline which is depicted as blue line. The edge of the runway is shown at the bottom of the figure in yellow. Sketch the trajectory but do not print the animation figures. Repeat the simulation and animation for the initial conditions $d = 1500m$ and $\psi = -10°$.