Problem Statement

MA8-3A

ALPHA-BETA TRACKER

Introduction

A satellite orbits the earth every two hours. Once each orbit, the satellite transmits data to a ground station, which can receive the transmission only during the 25 minutes per orbit that the satellite is above the horizon.

During each orbit, the satellite approaches the ground station from the western horizon, passes overhead, then recedes rapidly towards the east. The large relative velocity of the satellite with respect to the ground station gives rise to the *Doppler effect*. The frequency of the transmission as received on the ground is shifted with respect to the moving satellite. This can cause rejection of part of the desired signal, as shown in Figure 1.

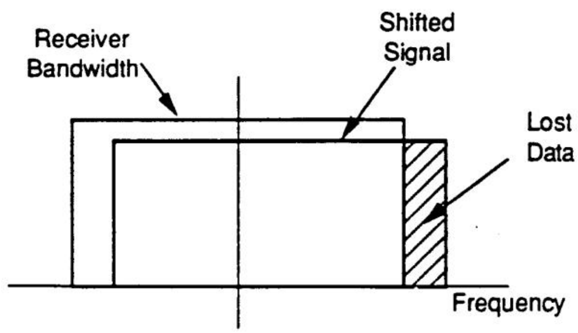

Figure 1. Data lost due to Doppler shift of satellite signal.

The ground station must constantly vary its receiver bandwidth (that is, retune the receiver) by matching frequencies with the shifting signal. This can be accomplished by a *phase-lock loop*, which measures the phase shift between the received signal and a local oscillator, then varies the local frequency to match the frequency received. A block diagram of the phase-lock loop is shown in Figure 2.

An important component of the phase-lock loop is the alpha-beta tracker, shown in block-diagram form in Figure 3. This component samples the phase error, $x(nT)$, between the local-oscillator and received-signal frequencies and produces the output, $y(nT)$, which is a smoothed estimate of the current phase shift.

The triangles in Figure 3 are fixed gains and the blocks are unit delays. The input, $x(nT)$, contains noise components due to orbital fluctuations, atmospheric and receiver noise, and other sources. The alpha-beta tracker acts as a filter to provide a smoothed signal for the receiver.

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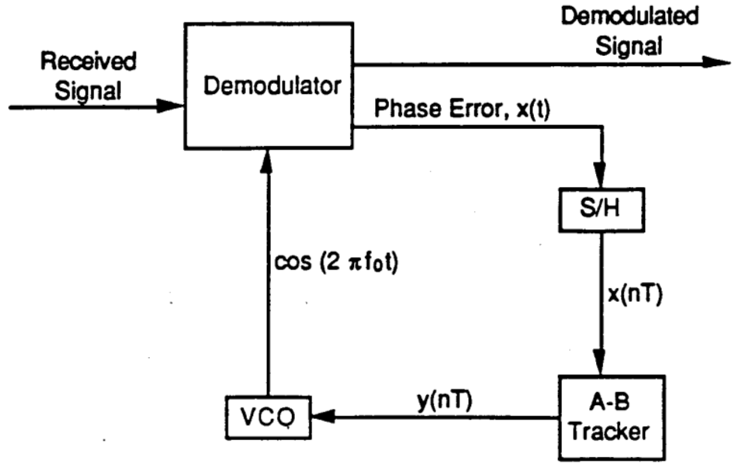

Figure 2 Phase-lock loop receiver.

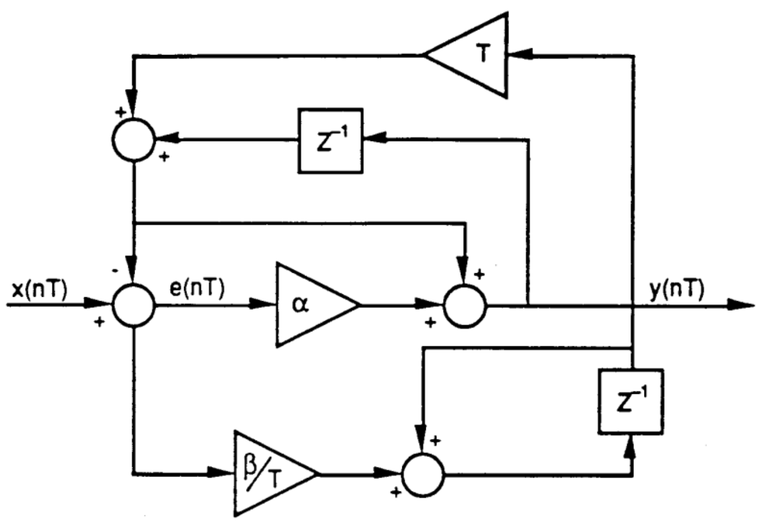

Figure 3. Alpha-beta tracker block diagram.

Assignment

Please find the following important characteristics of the alpha-beta tracker:

1. Determine the transfer functions from the tracker input to $y(nT)$ and to the tracker error signal, $e(nT)$.
2. Determine the gains, α and β, (nonnegative) for which the tracker is
   - unstable,

- stable and underdamped, and
- stable and overdamped.

Show the various regions on a single Cartesian plot, with α as the abscissa and β as the ordinate.

3. Determine the order of the alpha-beta tracker.
4. When the satellite first appears above the horizon, the initial Doppler shift is unknown and the phase-lock loop must accept all reasonable values of phase shift in $x(nT)$. It is important at this time that the alpha-beta tracker provide a relatively broad frequency response. After the phase-lock loop has reduced the phase error to near zero, $x(nT)$ will consist primarily of a slowly changing signal and higher-frequency noise. The tracker can then adjust α and β to better filter $x(nT)$, thus producing a smoother output, $y(nT)$.

   Are the gains, $\alpha = 1.0$ and $\beta = 1.0$, satisfactory for use during start up? How do these settings affect the filtering function of the tracker?
5. Plot the magnitude response of the alpha-beta tracker output, $y(nT)$, for the operating settings, $\alpha = 0.1$ and $\beta = 1.0$. Will the filter be effective in steady-state operation? Explain.

   Also, comment on the choice of β=1.0 compared to β=0.1 or β=0.01