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OPTIMIZATION OF THE EFFECTIVE GPS DATA RATE

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SUMMARY

Ohio University's Avionics Engineering Center is performing research directed towards the integration of the NAVSTAR Global Positioning System (GPS) and the Inertial Navigation System (INS) for attitude and heading determination. The integration of GPS/INS offers synergistic benefits. INS gyro drift error can be compensated by the long-term stability of GPS by means of an in-flight data monitoring algorithm. Using GPS data as a reference is more advantageous than implementing an additional INS since GPS offers a dissimilar redundancy to the attitude and heading determination configuration. In converse, the short-term stability of the INS can be used to correct or substitute for faulty GPS data due to tracking loop phase lag or data gaps because of satellite shielding.

The optimization of the effective GPS data rate is essential for the proper execution of an integrated GPS/INS in-flight algorithm. GPS attitude and heading information must be consistently available during INS outages. Present research efforts involve the development of an in-flight algorithm that maximizes the potential of integrated GPS/INS. This algorithm determines the acceptable limits of phase lag that the GPS tracking loop introduces to the flight control system (FCS) during the transmission of information. Once these calculated limits are exceeded, INS data are used to insure the continuous availability of attitude and heading information to the flight control system, as depicted in figure 1.

OVERVIEW OF GPS RECEIVER TRACKING LOOPS

Both code and carrier tracking loops are implemented in a GPS receiver to abstract navigation information. Each channel of the receiver measures an antenna phase center location on the aircraft (see figure 2). Through interferometric measurements, the receiver obtains the navigation signal. The GPS signal is tracked by the carrier and code tracking loops. Both tracking loops are based on phase-locked loop (PLL) principles. The phase-locked loop is a negative feedback system which consists of three principal components: a multiplier, a voltage-controlled oscillator (VCO) and a loop filter. A reference signal is generated by the VCO and is continuously adjusted until its phase is equal to the phase of the carrier component of the GPS input signal.

The GPS navigation code is retrieved by an analogous method implemented in the carrier tracking loop. The input code is compared with a locally - generated reference code. An early/late detector determines whether the two codes match through the use of a correlator. Once the code is acquired, it can be combined with the carrier component to be used as the real-time reference by the carrier tracking loop. As a result, both the code and carrier tracking loop functions are mutually dependent upon one another during the continuous tracking of the GPS signal, as shown in figure 3.

DETERMINATION OF THE EFFECTIVE GPS DATA RATE

The acceptable level of phase lag introduced by the GPS guidance information into the flight control system during, for instance, a precision approach is 6 degrees for a guidance-loop bandwidth of 1.5 radians per second. If this phase lag level is exceeded, the overall phase margin of the FCS becomes too small, thereby reducing the stability of the FCS. To optimize the GPS data rate, the tracking loop bandwidth in the GPS receiver must be designed to meet the above requirement. Too narrow a bandwidth will introduce a phase lag to the flight control system since the tracking loop configuration will take longer to track the signal dynamics. In converse, too wide a loop bandwidth will introduce excessive noise into the tracking loops.

Tracking loop bandwidth optimization can be achieved by characterizing a given tracking loop circuitry in a GPS receiver through computer simulation. In a simulation environment individual component parameters can be adjusted to narrow the loop bandwidth. The effective data rate is varied by changing the loop parameters. As the data rate approaches the limiting phase lag of the flight control system, the tracking loop bandwidth parameters will approach optimum values. If no satisfactory parameters can be determined, then additional information is required, which could be provided by an INS.

A sensitivity analysis will determine which parameters have the most effect on the phase response of the tracking loop circuitry. Since numerous combinations of parameter values can be combined to produce an equivalent phase response, practical design constraints will be considered to determine the optimum set of parameter values.

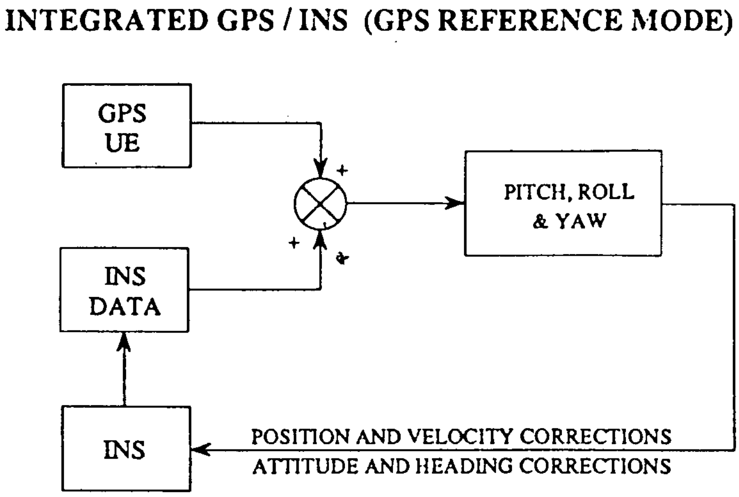

Figure 1. GPS/INS attitude and heading configuration.

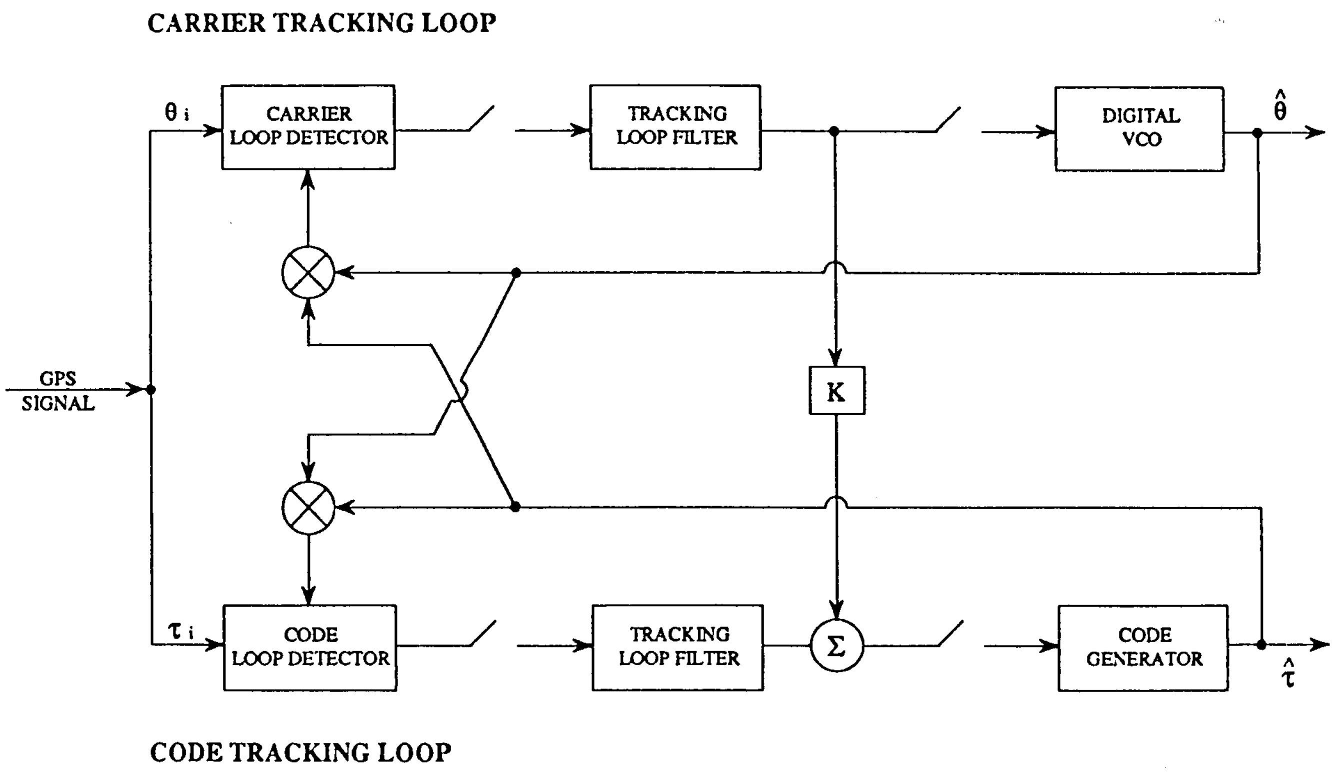

Figure 2. Simplified representation of GPS receiver tracking loops.

CONCLUSIONS

Once the effective GPS data rate is determined, the phase response of the transfer of data to the flight control system can be measured. Optimum loop parameters can be chosen to minimize phase lag through simulation.

If the effective GPS data rate is unacceptable during flight dynamics, inertial aiding must be implemented to increase the effective data rate presented to the FCS. The synergistic advantages of employing these two dissimilar systems contribute to a continuous supply of navigation information at an acceptable rate to the flight control system.

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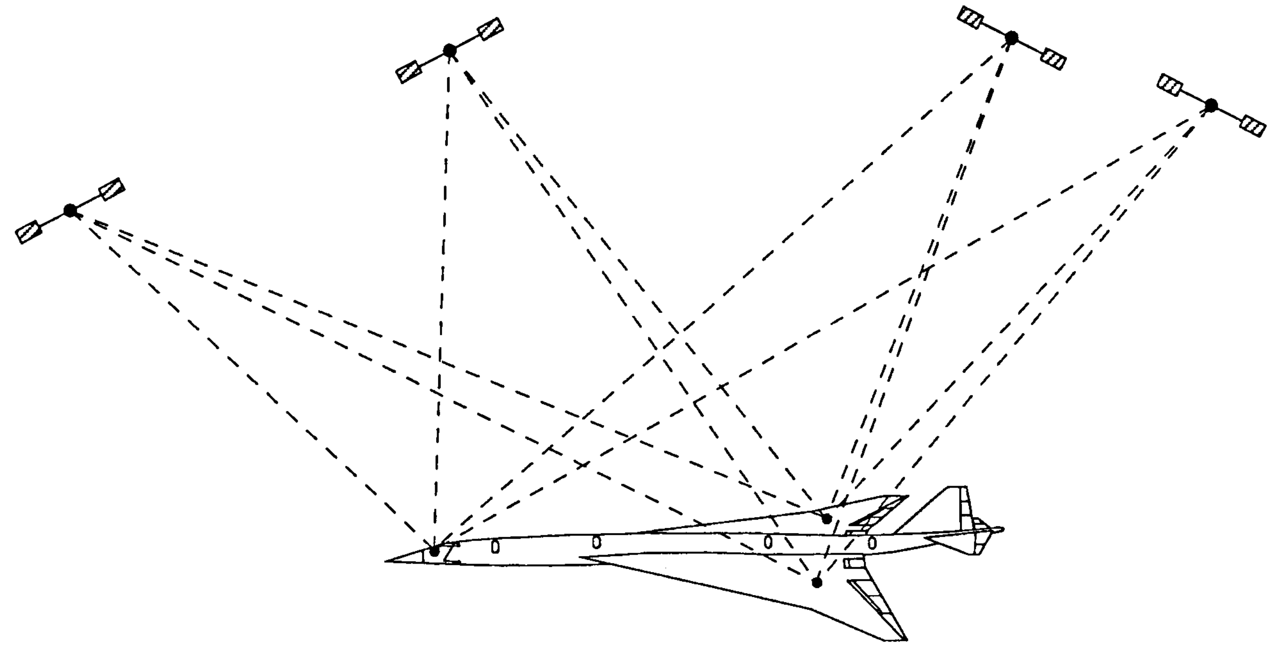

Figure 3. GPS Interferometric measurement scheme.