ABSTRACT. The attitude and orbital control system for the Indian Remote Sensing (IRS) Satellite to be put into the Sun-synchronous 10 O'clock polar orbit during 1986, has to meet very stringent body rate specifications of the order 0.0003 deg sec\(^{-1}\) in the normal-mode operation. In order to meet these low body rate specifications, an onboard microprocessor based observer is envisaged. Initial design of observer with errors and body rate estimates alone was found to be inadequate in the presence of disturbance torques. It was thus found necessary to modify the observer design in order to estimate the disturbance torques, thereby, improving the estimates of the body rates and attitude errors. In this paper various refinements attempted are examined, and some of the simulation results are presented.

1. INTRODUCTION

The Indian Remote Sensing (IRS) is essentially a 3-axis stabilized spacecraft using 4-reaction wheel, zero momentum concept. A reaction wheel is mounted along each of the principal axes, namely, Yaw, Roll and Pitch and a fourth reaction wheel referred to as the "Skewed Wheel" is mounted along an axis which makes equal angles with the three Principal axes. Each of these wheels is independently controlled by their corresponding PWPFM (Pulse-Width-Pulse-Frequency-Modulator) Controllers (Kudva, 1980) and the wheel drive electronics. The Yaw axis is pointed towards the earth, Roll axis along the velocity vector and Pitch along the negative orbit normal. The yaw error is derived from DTG which is updated twice in an orbit at around the poles using precision Yaw sensor. Roll and Pitch errors are obtained from the conical earth sensor. The design of the controllers has to take into account the characteristics of the sensor including noise and the bearing friction noise of the wheels since these are directly reflected on the spacecraft body rates and errors. It was found through extensive simulations that the body rate specifications of the order 0.0003 deg sec\(^{-1}\) cannot be met unless rate feed-back also is given to the controller. However, the rates of this order cannot be obtained from DTGs.
So an onboard microprocessor based observer is envisaged. The gist of this paper essentially is this observer. Initial design of observer with errors and body rate estimates alone was found to be inadequate in the presence of disturbance torques. The disturbance torques are due to improper open loop compensation of orbital coupling torques or the secular torques or torques produced internally by magnetic torques or other external torques. The orbital coupling torque due to momentum transfer between yaw and roll wheels is compensated by giving an equivalent, opposite analogue signal to wheel drive electronics obtained from the wheel speed measurement. In practice, this compensation can never be exact. Computer simulations indicated that such an inadequate compensation resulted in rather poor estimates of the errors and rates and in turn, the body rates are found to be higher than the specifications. It was thus found necessary to modify the observer design in order to estimate the uncompensated coupling torques, thereby, improving the estimates of the body rates and attitude errors.

2. SPACECRAFT EQUATIONS OF MOTION

Assuming Euler angles to be small, the spacecraft motion can be described by the following equations (Kaplan, 1976).

\[
\begin{align*}
I_W \dot{\psi} + \psi (W^2 I_{\omega z} - W^2 I_{\omega y} I_{\omega z}) + \dot{\phi} (I_{\omega z} W - I_{\omega y} W_{\omega z} - H_{\omega y} W_{\omega z} - T_{\omega z}) &= 0 \\
I_Y \dot{\phi} + \phi (W^2 I_{\omega z} - W^2 I_{\omega x} I_{\omega z}) + \dot{\psi} (I_{\omega x} W - I_{\omega z} W_{\omega x} - H_{\omega x} W_{\omega z} - T_{\omega x}) &= 0 \\
I_Z \dot{\theta} + \theta (W^2 I_{\omega z} I_{\omega x} + W^2 I_{\omega z} I_{\omega y} + \psi I_{\omega z} W_{\omega z} - H_{\omega x} W_{\omega z} - T_{\omega x} - T_{\omega y}) - \psi W_{\omega z} &= 0 \\
W_x &= \psi W_{\omega} \\
W_y &= \phi W_{\omega} \\
W_z &= \theta W_{\omega}
\end{align*}
\]

where \( \psi, \phi, \theta \) are the body pointing errors, \( W_x, W_y, W_z \) are the yaw, roll and pitch body rates. \( W \) is the orbital period \( H_{\omega x}, H_{\omega y}, H_{\omega z} \) and \( H \) are yaw, roll, pitch and skewed wheel angular momentum values. \( I_{\omega x}, I_{\omega y}, I_{\omega z} \) are the principal-axes moment of inertias.

The complete schematic block diagram of the close Loop control system for yaw-axis is given in Figure 1a. The control system quickly transfers angular momentum from body to the reaction wheels, thus, maintaining 3-axis stability keeping the body rates and pointing errors well within the required specifications.

3. THE OBSERVER

Here a few comments regarding the observer are in order.