1.7 REVIEW OF THE EQUATIONS OF MOTION

At this point it is useful to review the airplane equations of motion as derived so far. There are three sets of equations:

1. The force equations obtained by substituting Eqns (1.50) into Eqns (1.19).

2. The moment equations as stated in Eqns (1.25). Note that the effect of spinning rotors (Eqns (1.30) has been omitted!

3. The kinematic equations as expressed by Eqns (1.45).

These three sets are repeated here for convenience:

1. For the force equations in the airplane body–fixed axis system XYZ:

$$\text{Force along X:}\quad m(\dot{U} - VR + WQ) = -mg\sin\Theta + F_{A_x} + F_{T_x} \tag{1.51a}$$

$$\text{Force along Y:}\quad m(\dot{V} + UR - WP) = mg\sin\Phi\cos\Theta + F_{A_y} + F_{T_y} \tag{1.51b}$$

$$\text{Force along Z:}\quad m(\dot{W} - UQ + VP) = mg\cos\Phi\cos\Theta + F_{A_z} + F_{T_z} \tag{1.51c}$$

2. For the moment equations in the airplane body–fixed axis system XYZ:

$$\text{Rolling moment about X:}\quad I_{xx}\dot{P} - I_{xz}\dot{R} - I_{xz}PQ + (I_{zz} - I_{yy})RQ = L_A + L_T \tag{1.52a}$$

$$\text{Pitching moment about Y:}\quad I_{yy}\dot{Q} + (I_{xx} - I_{zz})PR + I_{xz}(P^2 - R^2) = M_A + M_T \tag{1.52b}$$

$$\text{Yawing moment about Z:}\quad I_{zz}\dot{R} - I_{xz}\dot{P} + (I_{yy} - I_{xx})PQ + I_{xz}QR = N_A + N_T \tag{1.52c}$$

3. For the kinematic equations:

$$\text{Roll rate about X:}\quad P = \dot{\Phi} - \dot{\Psi}\sin\Theta \tag{1.53a}$$

$$\text{Pitch rate about Y:}\quad Q = \dot{\Theta}\cos\Phi + \dot{\Psi}\cos\Theta\sin\Phi \tag{1.53b}$$

$$\text{Yaw rate about Z:}\quad R = \dot{\Psi}\cos\Theta\cos\Phi - \dot{\Theta}\sin\Phi \tag{1.53c}$$

By substituting Eqn (1.35) into Eqn (1.34) followed by substitution of Eqn (1.34) into Eqn (1.33) the following relation is obtained between the earth axes velocity components and the body axes velocity components of the airplane:

$$\begin{Bmatrix} \dot{X}_e \\ \dot{Y}_e \\ \dot{Z}_e \end{Bmatrix} =$$

$$\begin{bmatrix} \cos\Psi & -\sin\Psi & 0 \\ \sin\Psi & \cos\Psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\Theta & 0 & \sin\Theta \\ 0 & 1 & 0 \\ -\sin\Theta & 0 & \cos\Theta \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\Phi & -\sin\Phi \\ 0 & \sin\Phi & \cos\Phi \end{bmatrix} \begin{Bmatrix} U \\ V \\ W \end{Bmatrix} \tag{1.36}$$

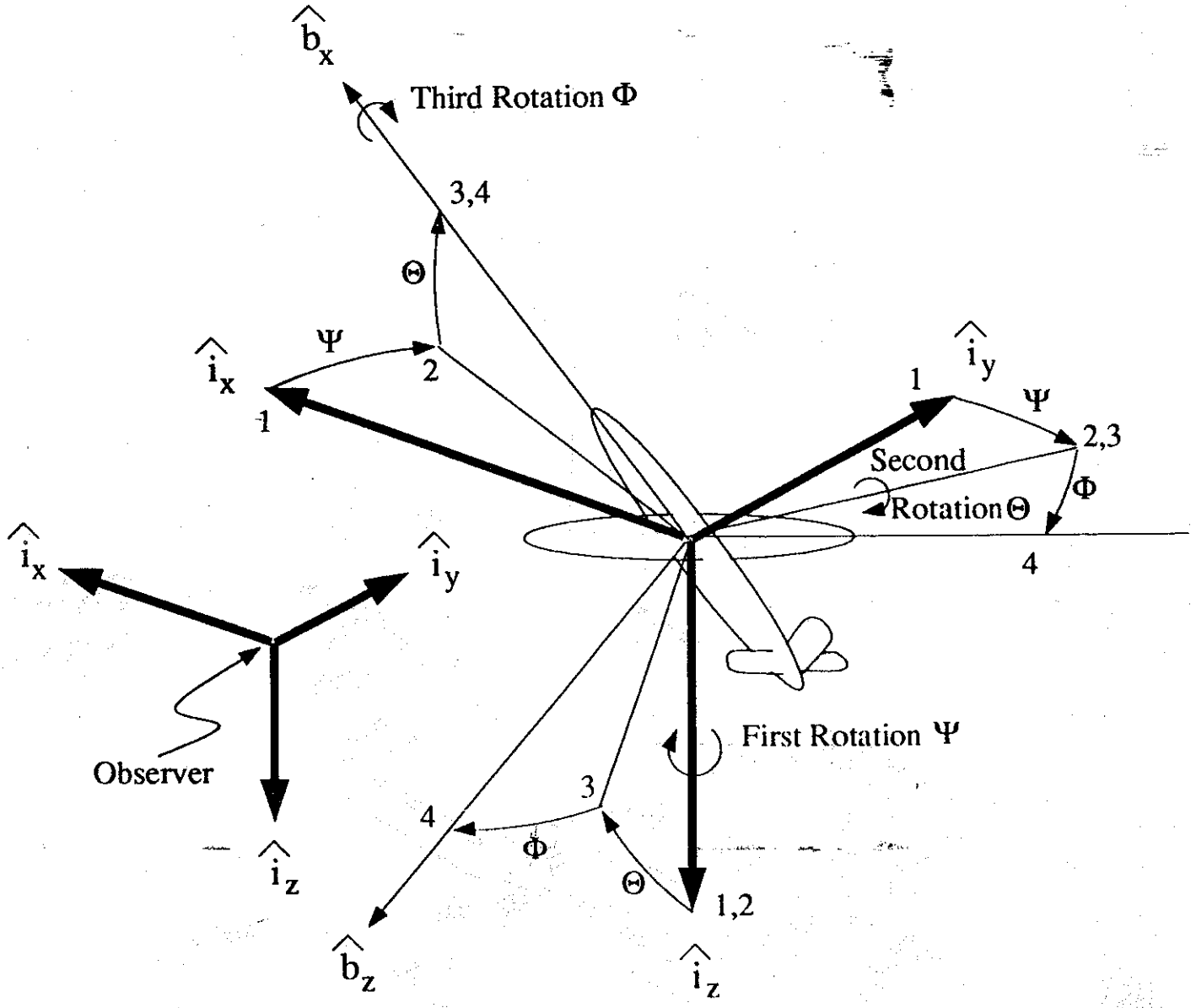

FIGURE 3 Definition of fixed wing aircraft and helicopter Euler angles.

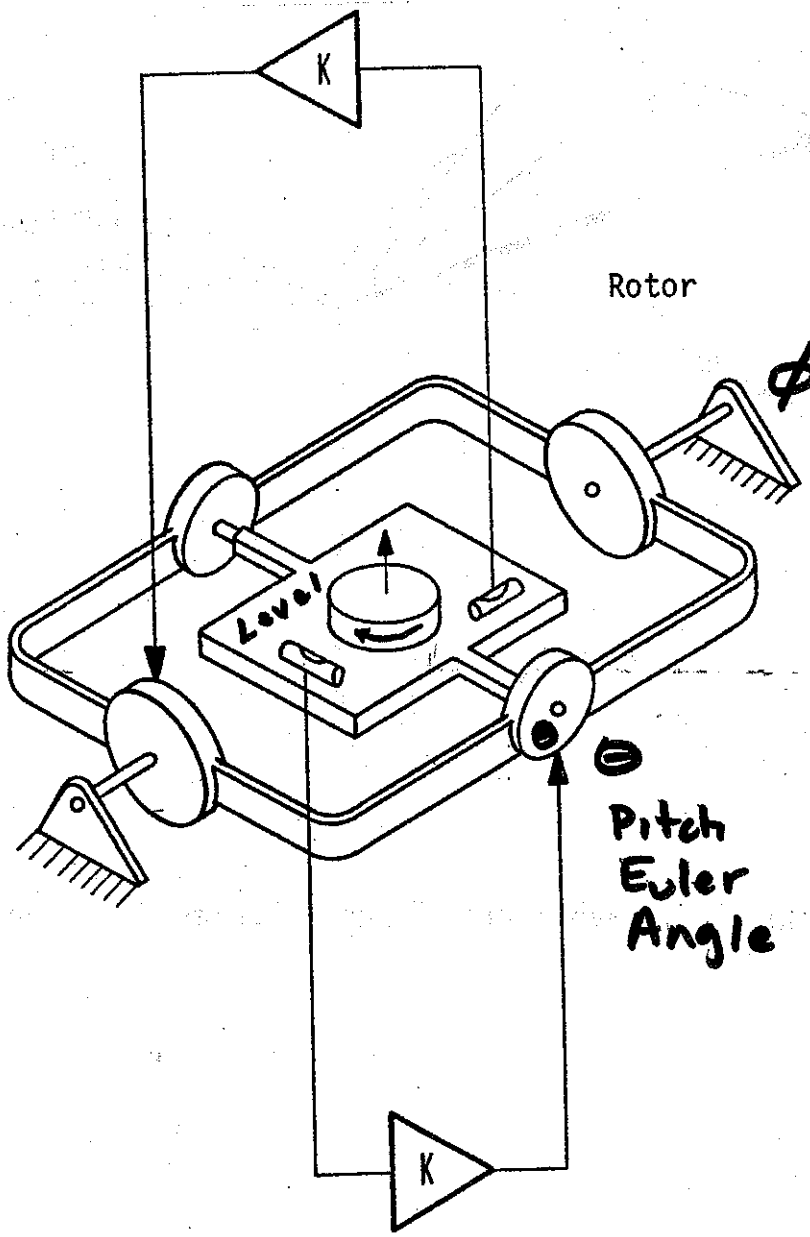

Fig. 6.1.1 Vertical Gyro Principle

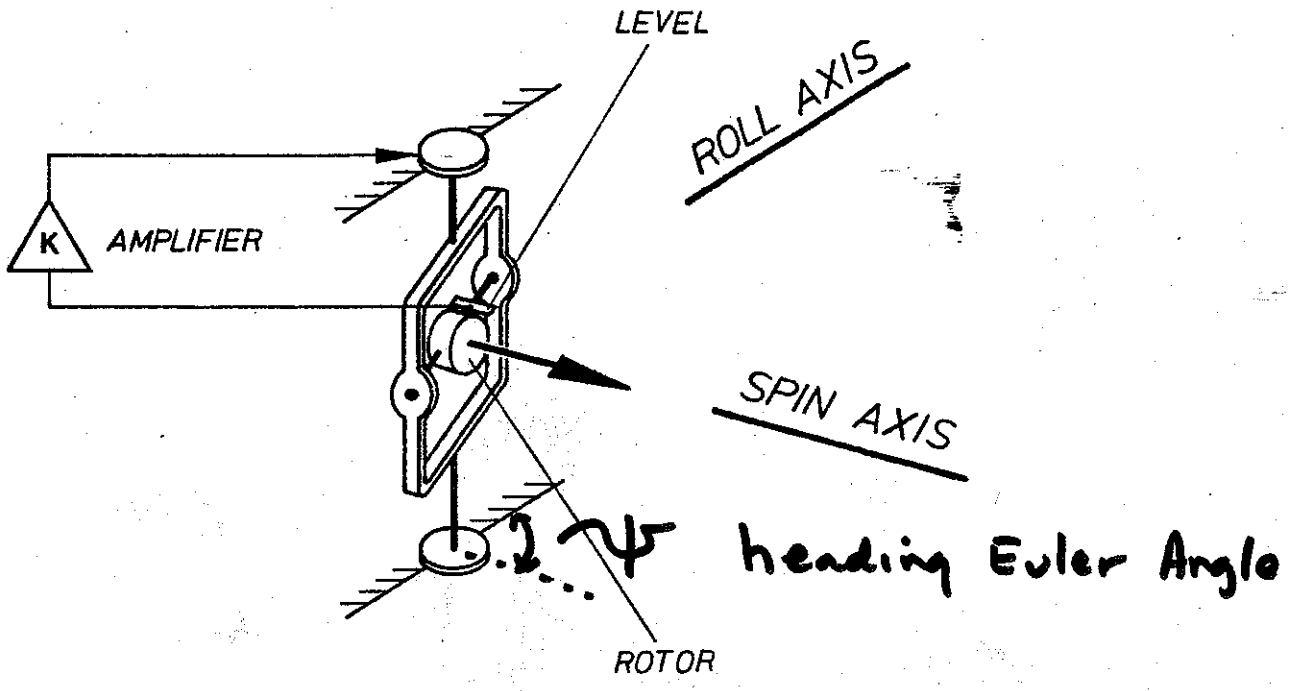

Fig. 6.2.1 Directional Gyro Principle

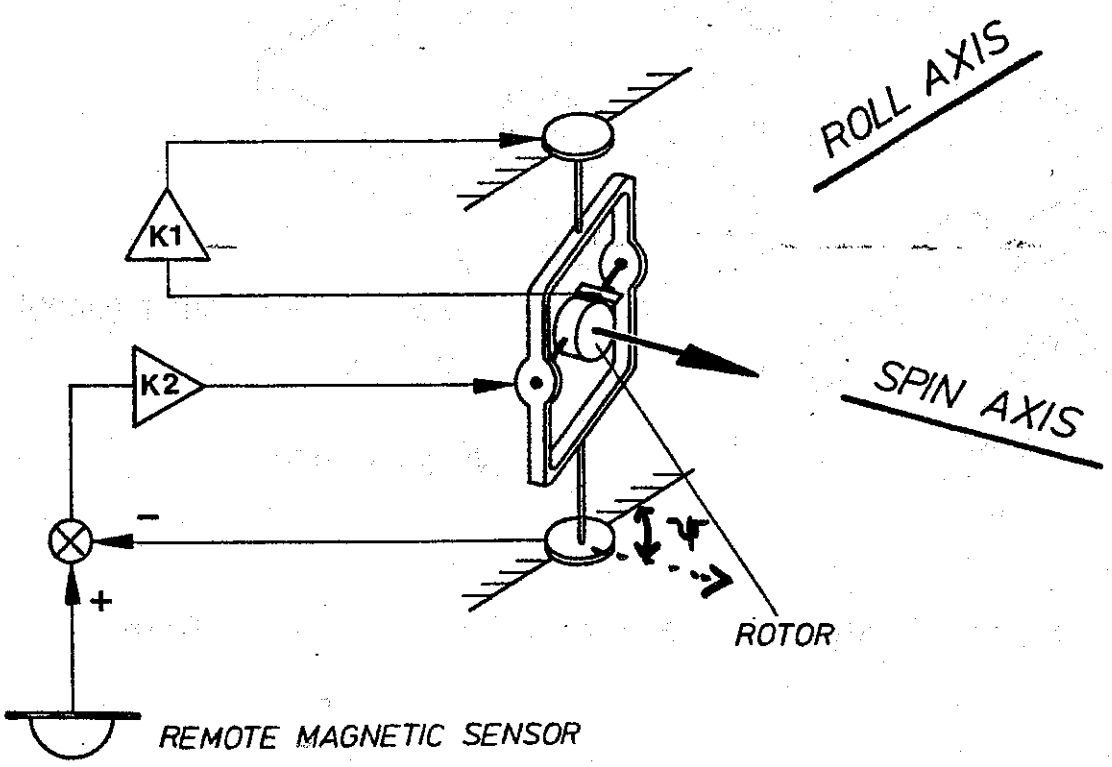

Fig. 6.2.2 Directional Gyro in the Slaved Mode

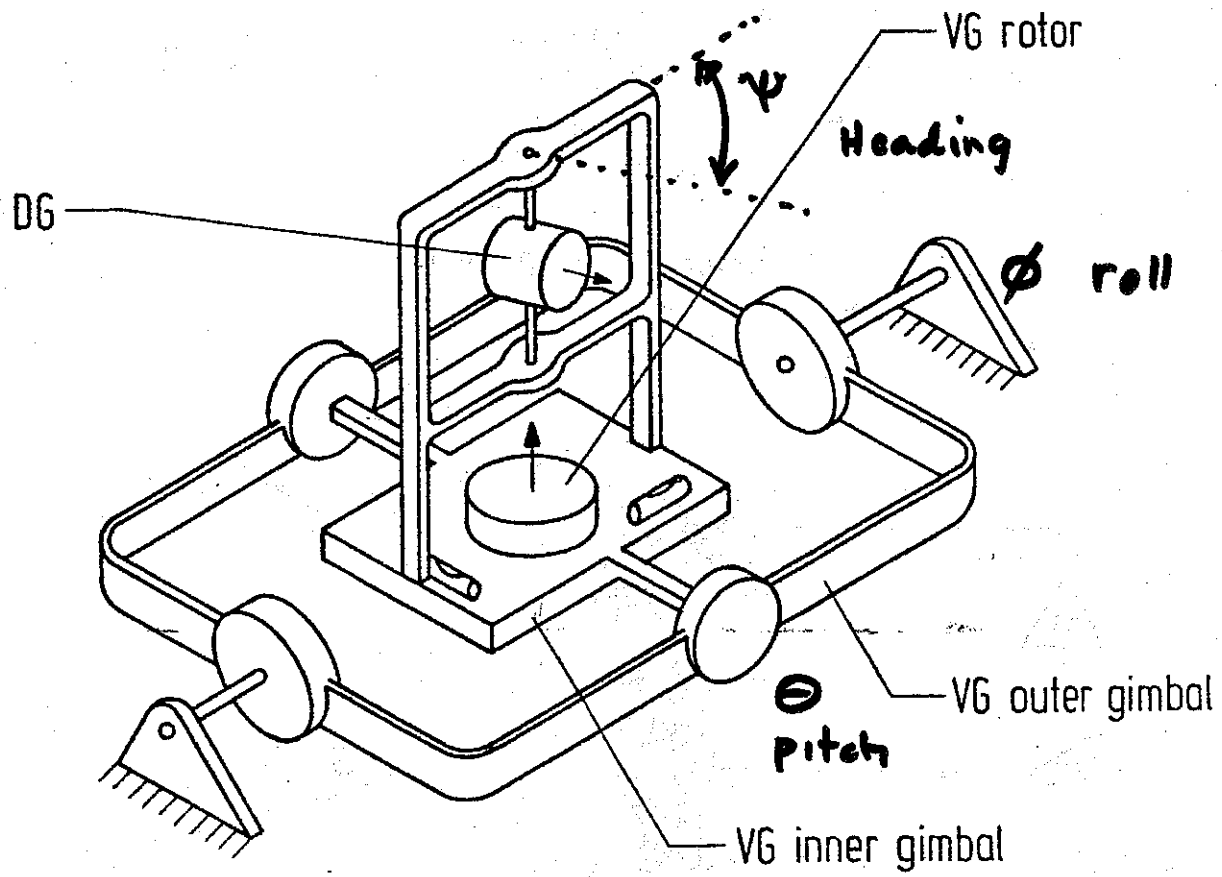

Fig. 6.3.1 Attitude and Heading Reference System Principle