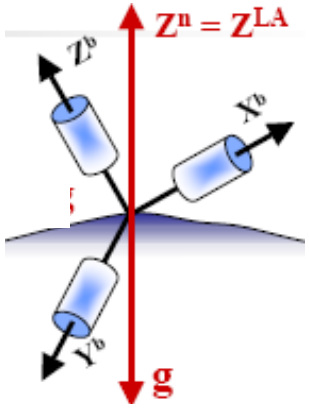
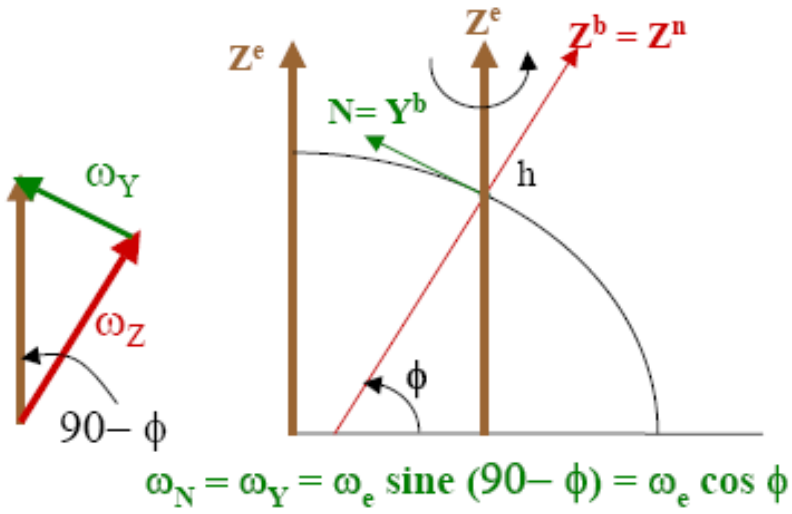
Principle of INS alignment

- Accelerometer leveling
  - Aligns the z-axis of the accel. triad to the z-axis of the navigation frame by driving the output of the horizontal accel. (x,y) to zero.

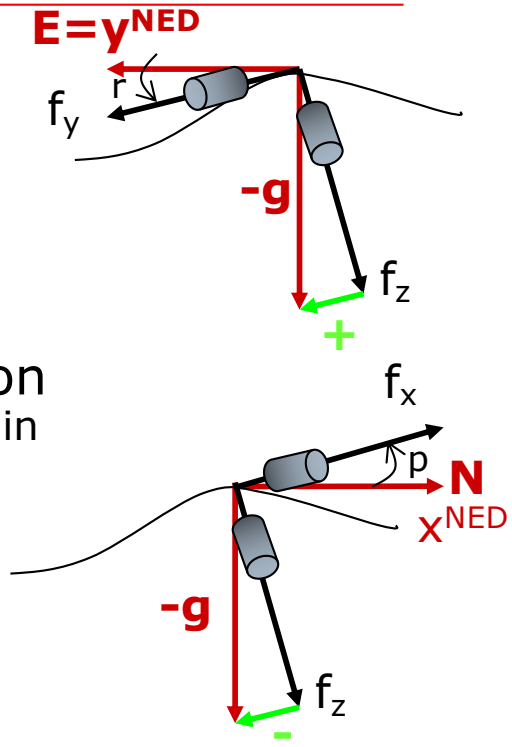


- Gyro compassing
  - After accel. leveling, the gyro with sensitive axis in the horizontal plane will sense a component of Earth rotation (ω_e).
  - This component will be maximum ($\omega_e \cos\Phi$) when the sensitive axis points to North; and minimum (zero) for East direction



Accelerometer leveling

- In error-free measurements, the f_x f_y readings represent the tilt in the x,y directions:
  - f_y = -g sin(r) ; -f_x = -g sin (p);
    - Where "r"=roll is the inclination in y-direction (rotation around x-axis) and "p"=pitch is the inclination in the x-direction (rotation around round y-axis).
  - r= asin(-f_y /g) -> roll
  - p = asin(f_x /g) -> pitch



- True vertical is established by driving f_x, f_y to zero
  - Mathematically (strapdown)
  - Mechanically (gimbled)

Gyro compassing (1/2)

- Assumption
  - Accelerometer **leveling already done**! = The output of x,y accel's is known in a level plane.
  - The x,y, **accel's** can be arbitrarily rotated in the **level-plane** about azimuth angle.
  - With the knowledge of roll & pitch, the output of *gyros* is *rotated* from body to level-plane (*l'*)

$$\omega_{ib}^{l'} = \left(R_1(r) R_2(p) \right)^T \omega_{ib}^{b}$$

Gyro compassing (2/2)

- The x-gyro measurements are given (NED)

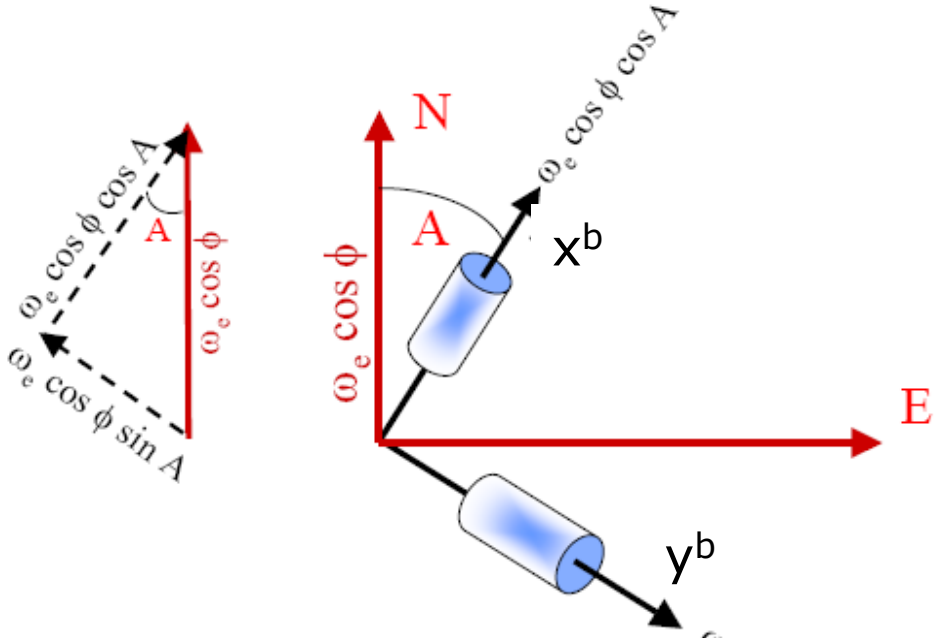
$$\omega_x^{l'} = \omega_e \cos\phi \cos Az$$

- The y-gyro measurements are given (NED)

$$\omega_y^{l'} = -\omega_e \cos\phi \sin Az$$

- The Azimuth is obtained

$$\tan Az = \frac{-\omega_y^{l'}}{\omega_x^{l'}}$$



- Note:
  - knowledge of latitude is not needed

Accel. leveling – limiting factors

- Q1 – What is the expected accuracy derived from leveling process?
  - Since (in NED):
    - $\sin(r_x) = -f_y/g$ -> roll
    - $\sin(p_y) = f_x/g$ -> pitch
  - The roll, pitch accuracy is governed by accel's. accuracy (mainly bias). For small angles:
    - $\Delta r = -b(f_y)/g$
    - $\Delta p = b(f_x)/g$
  - Example: 10mg bias -> leveling error of …?