#### Earth-Centered Earth Fixed and Geodetic Coordinate Frames

The *Earth Centered Earth Fixed* (ECEF) orthogonal coordinate system is fixed to the Earth and therefore it rotates at the Earth’s sidereal rate. The frame is usually denoted. It has its origin at the center of the Earth with  and axes placed in the equatorial plane and axis aligned with the direction of the Earth’s rotation vector, see Figure 3. The axis is usually attached to the intersection of the Greenwich meridian and the equator, and the axis completes the right hand system. It is worth noting that the ECEF axes definition may vary; however, the definition always states the attachment of two vectors to the direction of the Earth rotation and the Greenwich meridian as the inherent Earth properties. The sidereal rate  is the rate of Earth’s rotation with respect to the distant stars (the true inertial frame). If necessary, for the purpose of UAV flight description, this rate can be accurately approximated by one full rotation in 23h56’4.099”, thus resulting in 15.04106718 deg/h.



Figure 3. ECEF and geodetic coordinate frames.

The *Local Geodetic* { } frame is usually associated with the ECEF frame, see Figure 3. It has the same origin at the center of the Earth. The frame defines the orientation of the line normal to Earth’s surface and passing through the point of interest. The orientation of the line is defined by two angles, – geographic latitude and – geographic longitude, with the height above the Earth’s surface; these three parameters, along with the components of velocity vector, are the major navigation states. For most UAV applications it is sufficiently accurate to model Earth’s surface as an oblate spheroid with given -equatorial and -polar radiuses, or one of the radiuses and the -ellipticity. Last revisited in 2004, the datum of World Geodetic System (WGS-84) provides the following parameters for the oblate spheroid modeling: ,. The resulting transformation from the geodetic { } to the ECEF frame is as follows:



where - the eccentricity of oblate ellipsoid is defined as

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