Description of Geometric Altitude for the EGPWS

AlliedSignal Electronic & Avionics System

Geometric Altitude

Geometric Altitude is a computed aircraft altitude designed to help ensure optimal operation of the EGPWS Terrain Awareness and Display functions through all phases of flight and atmospheric conditions. Geometric Altitude uses an improved pressure altitude calculation, GPS Altitude, Radio Altitude, and Terrain and Runway elevation data to reduce or eliminate errors potentially induced in Corrected Barometric Altitude by temperature extremes, non-standard altitude conditions, and altimeter miss-sets. Geometric Altitude also allows continuous EGPWS operations in QFE environments without custom inputs or special operational procedures.

Background

Aircraft altitude, along with horizontal position and the terrain and obstacle database, are used to provide Terrain Awareness Display and "Look-Ahead" alerting and warning functions of the EGPWS. In order to ensure that timely alerts are provided and to minimize the potential for nuisance warnings, the EGPWS requires an accurate geometric altitude compatible with the elevation data contained in the terrain database.

The primary source of altitude for aircraft operations is normally Corrected Barometric Altitude. Corrected Barometric Altitude is provided by an Air Data Computer (ADC) using measured external static pressure and local pressure correction as entered by the flight crew. Corrected Barometric Altitude may be in error when compared to the true altitude, especially under extreme temperatures or non-standard atmospheric conditions such as inversion layers or strong pressure gradients. Corrected Altitude is also prone to errors induced by altimeter miss-sets and is not compatible with the EGPWS functions while operating under QFE conditions.

Uncorrected Barometric (or Standard) Altitude is also available from the ADC. Uncorrected Altitude is not susceptible to QFE and altimeter miss-set errors but is not compensated for local pressure variations.

An alternate source of altitude information is GPS, which provides a Geometric Altitude and is not significantly affected by atmospheric conditions. The overall accuracy of GPS Altitude however, is not typically sufficient to be used directly by the EGPWS, primarily due to errors induced by Selective Availability. However, GPS Altitude can be used in combination with other signals to provide a reliable estimate of its real time accuracy, which then can be used for reasonableness checking of other altitude sources.

Since no single sensor can provide an accurate geometric altitude through all phases of flight and atmospheric conditions, the EGPWS computes an estimated average altitude using Pressure and GPS Altitudes, aircraft position, and the internal runway and terrain databases. This is the Geometric Altitude function as described below.

With the Geometric Altitude function, EGPWS can operate reliably throughout extreme local pressure or temperature variations from standard, is not susceptible to altimeter miss-sets by the flightcrew, and will not require any custom inputs or special procedures by the flightcrew when operating in a QFE environment.

Required Inputs

The Geometric Altitude computation requires GPS Altitude with Vertical Figure of Merit (VFOM) and RAIM failure indication along with Standard (Uncorrected) Altitude and Radio Altitude. Ground Speed, Roll Angle, and Position (Latitude and Longitude) are used indirectly and are also required. Additionally, Corrected Barometric Altitude, Static Air Temperature (SAT), GPS Operational Mode and the Number of Satellites Tracked are used if available.

The required GPS signals can be provided directly from an external ARINC 743 / 743A receiver or from the optional internal EGPWS Xpress GPS Receiver card. Standard Altitude, Corrected Barometric Altitude, and Static Air Temperature (SAT) are provided directly from the ADC. If SAT is not available, geometric altitude is computed using Standard Altitude with a corresponding reduction in accuracy.

Altitude Calculation

The Geometric Altitude consists of three main functions: Calculation of Non-Standard Altitude, calculation of the component altitudes and VFOMs, and the final altitude signal blending. Additional logic exists to handle reversionary modes and signal reasonable checking for each component altitude. An overview of the Geometric Altitude function is shown in figure 1.

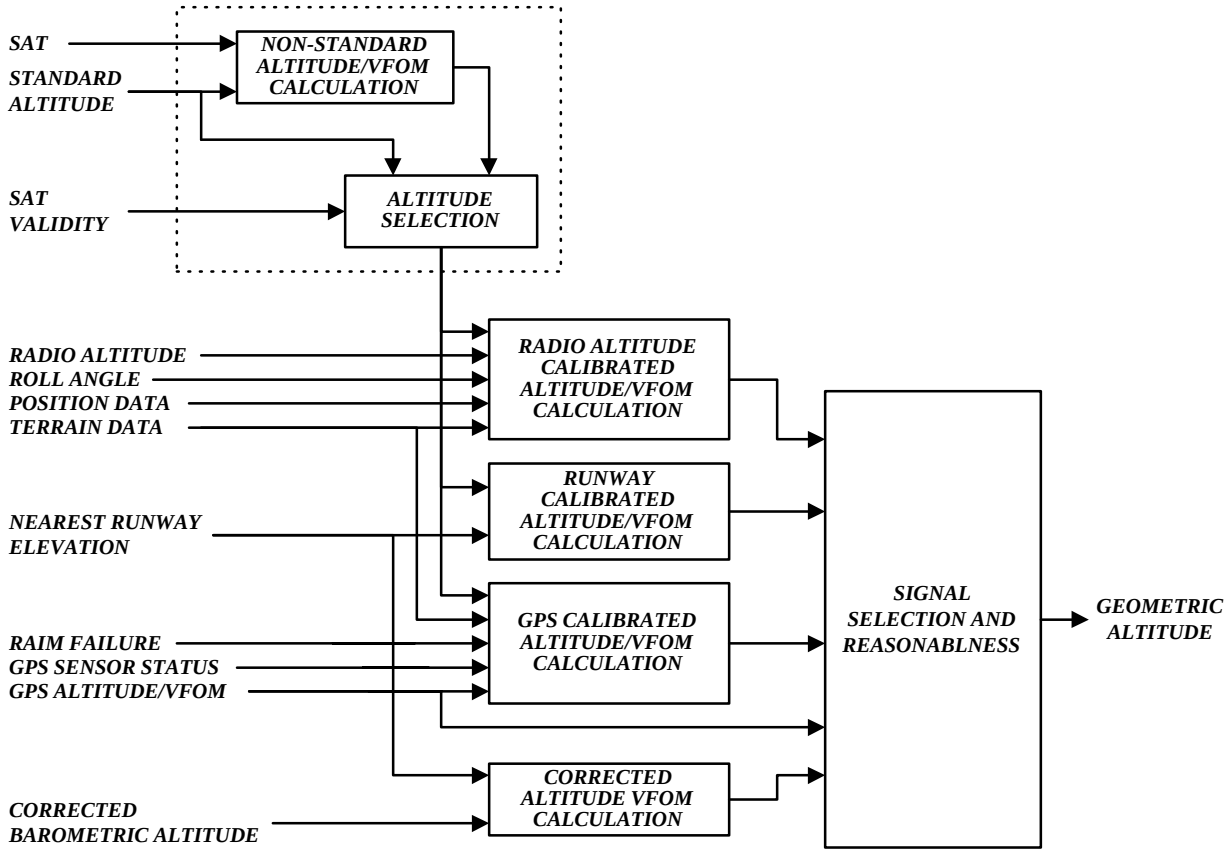

Figure 1: Geometric Altitude Block Diagram

Non-Standard Altitude

To support the Geometric Altitude function the EGPWS computes a Non-Standard Altitude using the hydrostatic equation relating changes in height to changes in pressure and temperature. Non-Standard Altitude uses static pressure derived from standard pressure Altitude, along with static air temperature, to continuously accumulate changes in geometric altitude. Since the Non-Standard Altitude algorithm incorporates actual atmospheric temperature it does not suffer from errors due to non-standard temperatures.

Non-Standard Altitude is highly accurate for measuring relative vertical changes over short periods of time and distance, such as during take-off and approach. Non-Standard Altitude does not provide an absolute altitude and is prone to significant errors over extended periods of time and distance due to the effects of pressure gradients and long term integration errors. Due to these limitations, Non-Standard Altitude is not used directly, but is calibrated using additional signals and data to produce a set of component altitudes for use in the final altitude solution.

Computed Component Altitudes

The EGPWS generates three component altitudes that are combined, along with Corrected Altitude if available, to produce Geometric Altitude. These component altitudes are Runway Calibrated Altitude, GPS Calibrated Altitude, and Radio Altitude Calibrated Altitude.

Runway Calibrated Altitude, is a one-time calibration of Non-Standard Altitude during take-off roll. A correction factor for Non-Standard is computed using the runway elevation from the EGPWS Runway database while the aircraft is on the ground. Runway Calibrated Altitude is used during the take-off and climb-out portions of flight. VFOM of Runway Calibrated Altitude is estimated based on changes in altitude since calibration, time since calibration, and distance from the runway.

GPS Calibrated Altitude is produce by combining GPS Altitude and Non-Standard Altitude through a complementary filter. The complimentary filter is dynamically optimized to reduce errors in GPS Altitude caused by selective availability while minimizing pressure gradient and drift errors of Non-Standard Altitude. GPS Calibrated Altitude is accurate through all phases of flight and is the primary altitude source during the cruise portion of flight. GPS Calibrated Altitude VFOM is estimated using GPS VFOM and estimated Non-Standard Altitude drift errors.

Radio Altitude Calibrated Altitude is a calibration of Non-Standard Altitude during approach using an altitude derived from radio altitude (height above terrain) and the terrain elevation data stored in the EGPWS terrain database. This calibration is performed during the approach phase of flight when the aircraft is within a minimum distance and elevation of any runway. Once a correction factor is determined, it is applied to Non-Standard Altitude until the aircraft lands. VFOM of Radio Altitude Calibrated Altitude is based on the accuracy of the calibration as estimated from the flatness of the terrain and Non-Standard Altitude drift errors. The altitude is re-calibrated if a correction with a higher estimated accuracy is computed.

An estimated VFOM for Corrected Barometric Altitude is computed in order to determine its weight in the final altitude. VFOM of Corrected Barometric Altitude is based on aircraft altitude above and distance from the nearest runway, with the accuracy assumed to be the highest close to runway.

Blending and Reasonableness Checking

The final Geometric Altitude is computed by combining the three computed component altitudes with optional Corrected Barometric altitude. The weighting of each altitude in the final solution is based on the corresponding estimated VFOM. The blending algorithm gives the most weight to altitudes with a higher estimated accuracy, reducing the effect of less accurate altitudes on the final computed altitude. Each component altitude is also checked for reasonableness using a window monitor computed from GPS Altitude and GPS VFOM. Altitudes that are invalid, not available, or fall outside the reasonableness window are not included in the final blended altitude.

Input Failures and Reversionary Operation

The Geometric Altitude algorithm is designed to allow continued operation when one or more of the altitude components are unavailable. Component Altitudes that are unavailable due to a failed input signal or flagged as unreasonable are not used, with the final blended altitude comprised of the remaining, valid signals. If all component altitudes are invalid or unreasonable, then GPS Altitude is used directly for the Terrain Awareness functions. If the installation is not configured for GPS Altitude then the Terrain Awareness functions operate using Corrected Altitude.

For installations without SAT or if the SAT input fails, Standard Altitude is use in place of computed Non-Standard Altitude. Under such conditions, all computed component altitudes normally requiring Non-Standard Altitude use Standard altitude with a corresponding decrease in accuracy. When using Standard Altitude in place of Non-Standard Altitude, affected estimated VFOMs are adjusted resulting in the affected signals being weighted less heavily in the final blended altitude.