Radio Altimeter

Radio Altimeters are only active at low levels.

From 5000ft to the surface in older equipment and from 2500ft down in modern equipment.

The primary function of Radio Altimeters is to provide accurate Decision Height (DH) information where precision approaches are flown to a DH of less than 200ft.

Radio altitude is also used as an input to the Ground Proximity Warning System (GPWS) and TCAS.

System Operation

The basic concept is that a radio beam is directed at the ground in a 30° cone and the signal reflected back to the aircraft.

Most radars work by timing how long the signal takes to travel to the target (in this case the ground) and back.

However when the aeroplane is very close to the ground the time delay for the returning signal is very small and difficult to measure.

Most radars also send and receive pulses of radar energy using a single aerial to do both jobs (by switching its function from transmit to receive)

At very short ranges this idea also fails because the aerial cannot switch from transmit to receive quickly to catch the returning pulse.

Radio Altimeters consequently use a continuous wave radar rather than a pulse radar.

This needs separate transmitter and receiver aerials.

These are usually located under the fuselage near the gear position.

The readings are zeroed to compensate for both aerial height and the wiring inside the aircraft so that the altimeter reads zero when the wheels touch down in the landing attitude.

Continuous wave radio altimeters do not measure the time delay for the returning signal (like other radars).

The transmitted frequency sweeps up and down through a range of about 200MHz centred on 4300MHz.

The difference between the frequency being transmitted and the one returning (beat frequency) is a measurement of height.

Accuracy

+/- 2 feet in the first 500 feet or +/- 1.5% whichever is greater.

Ground Proximity Warning System (GPWS)
The GPWS provides (audible signals which may be supplemented by visual signals) warning of:

- Sink rate - Mode 1
- Ground proximity - Mode 2
- Altitude loss after take-off or go-around - Mode 3
- Incorrect landing configuration - Mode 4
- Downward glideslope deviation - Mode 5
- Automatic height calls, warnings of excessive bank angle - Mode 6
- Windshear - Mode 7

The Standard GPWS has primarily a “Look Down” logic.

Since it cannot "Look Forward", it cannot warn soon enough of the rapidly rising terrain on the same flight paths.

Therefore an Enhanced GPWS (EGPWS) includes a Terrain Awareness Warning System (TAWS).

TAWS is a forward looking terrain avoidance function and provides visual and aural display of terrain forward of the aircraft.

EU-Ops states that an operator shall not operate a turbine powered aeroplane having a maximum take-off mass greater than 5700 kg or an approved configuration of more than nine passenger seats unless it is equipped with a GPWS which includes a TAWS.

**Mode 1**

It gives warning of excessive barometric rate of descent (greater than approx 3 times the radio height).

It gives the alert "SINK RATE, SINK RATE"

It is active below 2500 ft radio.

If the high rate of descent is maintained closer to the ground the alert becomes the warning "WHOOP WHOOP, PULL UP".

**Mode 2**

It is triggered by reducing radio altitude and warns of rising ground beneath the aircraft.

The initial alert is "TERRAIN, TERRAIN".

If the situation worsens the alert is replaced by the warning "WHOOP, WHOOP. PULL UP"

It is repeated continuously until the radio altitude has stopped reducing and an increase of 300 ft baro altitude is registered.
Mode 1 and Mode 2 together are capable of dealing with most Controlled Flight Into Terrain (CFIT) incidents.

However, the major input for mode 2 is radio altitude.

And the radio altimeter only senses terrain in a 30° cone below the aircraft. Therefore neither Modes 1 or 2 will prevent flying straight into a vertical cliff face.

**Mode 3**

It warns of barometric height loss after a take-off or go-around.

For this mode to be active the flap selector must not be in the "landing flaps position" and the gear should be selected up.

On some aircraft throttle position is also an input.

The alert is "DON'T SINK, DON'T SINK".

There is no warning.

**Mode 4**

It warns of closeness to the ground without the appropriate gear and flap selections.

**At High Speed**

At high speed the aircraft is unlikely to be making an approach.

So the aim is to inform the pilot of ground proximity.

The audio is "TOO LOW TERRAIN".

**At Low Speed**

At lower speeds, if the aircraft is close to the ground and does not have either gear or flaps selected, the aim is to alert about the unusual configuration.

The alerts are "TOO LOW, GEAR" or "TOO LOW, FLAPS" as appropriate.

*Some National Authorities regard the high speed "TOO LOW, TERRAIN" as a warning (not an alert) and requires an immediate climb manoeuvre*

**Mode 5**

It gives warning of deviation below the glideslope.

It is armed when a valid signal is received on ILS and in a specified radio height bracket.

The alert is "GLIDESLOPE, GLIDESLOPE"
Initially at half volume, then if the situation worsens, faster and at full volume.

**Mode 6**

It includes height and bank angle call outs designed to increase situational awareness.

Mode 6 is not required by OPS-1.

It calls out "MINIMUMS MINIMUMS" as the radio decision height is passed.

More advanced systems automatically call out customer specified radio heights in the latter stages of the approach.

It can even include the command "RETARD" to retard the throttles on landing.

It can include an alert of excessive bank angle, "BANK ANGLE BANK ANGLE"

The thresholds for this alert vary by type and with radio height (more sensitive near ground).

**Mode 7**

It provides windshear alerts and warnings.

It is not required by OPS-1.

GPWS detects windshear from inputs including air data, temperature, rate of climb or descent, angle of attack, radio height, vertical & longitudinal acceleration from the IRS etc.

Some installations have separate amber and red windshear warning lights.

When windshear is initially detected the audio alert "CAUTION WINDSHEAR" is given with an amber light.

Severe windshear gives a red light, and a siren or horn followed by the warning "WINDSHEAR, WINDSHEAR".

**Terrain Awareness Warning System (TAWS)**

TAWS of EGPWS operates by relating aircraft position, track and groundspeed derived principally from a 3D satellite fix to a mathematical model of the terrain.

The terrain database has global coverage but more resolution near airports with hard surface runways of 3500 ft or more in length.

The system shows terrain less than 2000 ft below aircraft altitude in a display similar to the weather radar display.

It is shown on the EHSI in Map mode or on a dedicated colour weather radar display.

Terrain is displayed in green, amber or red according to the degree of danger.
Terrain replaces the weather displays if the TERRAIN switch is selected.

Aural warnings are "CAUTION TERRAIN" followed by "TERRAIN, TERRAIN, PULL UP".

There is no "WHOOP, WHOOP" warning.

Red "PULL UP" lights illuminate.

The system generates a terrain clearance floor around the nearest stored airfield at heights roughly equivalent to a 3° approach.

Penetration of the floor generates a "TOO LOW, TERRAIN" warning.

The terrain floor is based on the nearest airfield and not the destination field.

If other fields are close to destination airfields then it can cause some confusion.

**Warnings and Alerts**

**Genuine**

Correctly generated in accordance with the system's technical specification.

**Nuisance**

Correctly generated in accordance with the set criteria.

However the situation is not unsafe e.g. TERRAIN TERRAIN on approach.

If in VMC and on an accepted procedure like an ILS then the alert is treated as spurious.

If in IMC then a go-around should be done.

**False**

Generated by the system but not in accordance with its technical specification.

**TCAS - Traffic Alert Collision Avoidance System**

It provides traffic information between aircraft using SSR transponders.

TCAS II provides manoeuvre advice in the pitching plane in the event of a conflict.

In USA the system is called TCAS.

In JAA documents it is referred to as ACAS (Airborne Collision Avoidance System).

JAR and EU OPS now require new aircraft with more than 19 passenger seats or with a MTOM of more than 5700kg to carry and use TCAS II.

Aircraft of more than 5700kg registered outside JAA and EASA states are required to have TCAS II.
fitted to operate in European RVSM airspace or in the North Atlantic Region.

**Principle of Operation**

The TCAS system uses a Mode S SSR to interrogate the SSR transponders of nearby aircraft (to plot their positions and relative velocities).

It also receives spontaneous transmissions, "squitters", from Mode S equipped aircraft.

A definition of squitter is a reply format transmission without being interrogated.

These “unsolicited replies” or squitters are used to provide TCAS II equipped airframes with the discrete address of the squittering airframe, to enable the TCAS II system to acquire and track the airframe using mode S formats UF/DF0 and UF/DF16.

*Squitter has its origins in distance-measuring equipment (DME) transmissions. The DME ground station would broadcast unsolicited replies or squitters.*

*When the airborne DME interrogator was in range, the squitter would be seen and the DME interrogator would then transmit a range interrogation and receive range replies from the DME ground station. This served to limit unnecessary transmissions over the air and optimized DME ground station-handling capability.*

*TCAS 2 systems use mode S squitters in a similar fashion; the TCAS just listens for the DF11 squitters, which contain the sending aircraft’s discrete address, thereby reducing the need to interrogate over the air. The discrete address, once obtained, is placed on the TCAS 2 processor’s roll call of addresses for ongoing tracking. Mode S technology has two types of squitter, a short (56 bit) DF11 acquisition squitter and the extended (112 bit) DF17 squitter.*

Bearings are obtained by using direction finding receiving aerials.

Distance is determined by using the time delay between transmitted and received signals.

Altitude is read off the Mode C response.

The TCAS computes the track and closing speeds of the transponding aircraft.

If it thinks that a collision is possible, it issues a warning.

If the time to impact is small it generates a pitch manoeuvre command to avoid the collision.

The TCAS can cope with replies from modes A, C or S transponders.

When both aircraft are equipped with TCAS II and mode S the advice on how to avoid a collision will be co-ordinated by the mode S data link between the two aircraft.

**Protected Airspace**

The system protects a small and variable volume of airspace around the aircraft.

This is known as the collision area (an area where a collision is possible).
The threat is determined in terms of time to enter the collision area. TCAS envelopes vary between equipment manufacturers.

Aircraft that are assessed as being likely to enter the collision area in between 35 to 48 seconds result in a Traffic Advisory (TA).

TA is an audio caution of "TRAFFIC TRAFFIC".

If the time to enter the collision area reduces to 15 to 35 seconds the system will generate a Resolution Advisory (RA).

RA is an audio command to Climb or Descend for avoiding the collision.

**Advisories Classification**

RAs can be sub-divided into Corrective Advisories and Preventative Advisories.

Corrective Advisories advise a change in rate of climb or descent.

Preventative Advisories command "MONITOR VERTICAL SPEED" and avoid certain rates of climb or descent.

When conflict is resolved the advice "CLEAR OF CONFLICT" will be given.

When both aircraft are equipped with TCAS II and a "threat" materialises, the mode S data link between the two aircraft provides co-ordinated and complimentary RAs.

The first aircraft to make the interrogation sends an 'intent' message to which the receiving aircraft reacts to in the opposite sense.

One aircraft will climb and the other descends.

**Range and Limitations**

The range outside terminal areas is 30nm and ±27000.

In a high density traffic area TCAS automatically reduces its interrogation rate and power (thus reducing the maximum range).

Surveillance to at least 6nm is guaranteed.

In certain circumstances relative bearing information may be unavailable or unreliable.

Bearing information is only used for display purposes.

It is not a part of the algorithm calculating the collision area.

Therefore both RAs and TAs will still be generated for conflicting no-bearing traffic.

If the intruder replies with no Mode C altitude TCAS assumes it is at the same height.
However in this case it will only issue a TA.

TCAS recognises the limitation when aircraft performance is limited like high altitude or with gear and flaps down.

It will therefore inhibit "CLIMB" and "INCREASE CLIMB" RAs.

All aural commands are inhibited by GPWS, Terrain and Windshear warnings.

The radio altimeter input is used to identify and discard returns within 360ft of the ground.

It will declare own aircraft on ground through air/ground logic systems and RADALT height less than 50ft.

As the radio altitude decreases, Resolution Advisories are inhibited:

- Increase in rate of descent RAs are inhibited below 1450ft radio altitude.
- Descent RAs are inhibited below 1100ft radio altitude.
- All RA’s are inhibited below 1000ft.
- All aural commands are inhibited below 500ft.

**Terminology and Colour Coding**

Transponding traffic not generating a TA or an RA and within 6nm and ±1200 ft is called Proximate Traffic.

Transponding traffic not generating a TA or an RA and outside 6nm and ±1200 ft is called Other Traffic.

Red indicates an immediate threat and is only used with an RA.

Amber represents a moderate threat and is only used with a TA.

Proximate Traffic is shown as a cyan or white (solid) lozenge (diamond).

Other traffic is shown as a cyan or white hollow lozenge.

e.g. **B777 TCAS**

**Pilot Response to TA and RA**

TAs are only for information.

The crew should liaise with ATC for separation.

The bearing information displayed is so unreliable that pilots should not manoeuvre on the basis of the TCAS display alone.

The crew response to an RA is disengage the autopilot and to follow the instructions smoothly and promptly.
Where the required action conflicts with ATC clearance the pilot must follow the TCAS RA for the purpose of avoiding immediate danger.

However he must inform ATC of his deviation from the clearance as soon as possible.

As soon as the advice "CLEAR OF CONFLICT" is received return to the assigned flight level.

TCAS aims to give a clearance of between 300-500ft to resolve the conflict without the excursion imposing on adjacent flight levels.

The pilot reaction time expected by the TCAS logic is 5 seconds, with the pilot achieving the pull up/push over in three seconds.

Pitch change requirements depend on speed.

Typical g values for a "CLIMB CLIMB" or "DESCEND DESCEND" are 0.25g, aiming for a 1500 ft/min rate of climb or descent.

For an enhanced RA, "INCREASE CLIMB" or "INCREASE DESCENT" the typical g values are 0.35g, aiming for a 2500 ft/min rate of climb or descent to be achieved in 2.5 seconds.