The Lowdown on Radio Altimeters

by **Squadron Leader E. G. Stickley, T Eng(CEI) FSERT,** FS1d, Inspectorate of Flight Safety

The radio altimeter is an important aid to safe instrument flight but, like its barometric cousin, is has some built-in limitations. However, these limitations are sometimes less well understood than those associated with the pressure altimeter. It may therefore be interesting to take a look at some real life incidents that have involved the use of radio altimeters.

PR Canberra. "Flying into a valley from the coast to photograph a bridge with the nose camera I knew that I was going to be IMC after the target. I asked the nav what was the highest ground to the north of the target. He said "1500 ft" so I turned right, climbed into cloud and levelled at 2500 ft. Shortly afterwards I noticed the rad alt height falling smartly through 500 ft. I initiated an emergency climb. The nav had miscalculated the turning radius and we had rolled out pointing at a 4500 ft hill."

Vulcan. "A simulated bombing attack was flown by the co-pilot at 300 ft and 320 knots. The Rad Alt 7B was operating normally on the 0 ft to 500 ft scale, the Rad Alt 6 was unserviceable. After the target the first pilot took control and commenced a climbing turn to 2000 ft, to remain clear of high ground at 1283 ft. During this manoeuvre the nav radar shouted "100 ft descending, climb, climb". The first pilot responded to this unexpected cry by increasing the rate of climb, which resulted in the aircraft being overstressed. Both pilots noticed the Rad Alt 7B indicating between 100 ft and 200 ft. The aircraft was levelled at 2500 ft VMC. The rad alt indicated a reading of 250 ft. The 0 ft to 5000 ft scale was selected and the height indicated 2500 ft."

Jaguar. "On entering a valley it became obvious that the weather ahead was not suitable. I decided to climb out and let down in clear weather to the west. I began a normal pull-up and confirmed HUD and HDD indications intending to climb to VMC on top. Shortly afterwards, in the climb, the HUD rad alt showed decreasing height. This caused confusion and a considerable degree of fright. I reached for the ejection seat handle and rechecked HUD and HDD pitch indications and also the HUD VSI. All indicated a climb. I came out of cloud at 7000 ft with the rad alt reducing through 500 ft."

In the calm atmosphere of the crewroom it is easy to analyse each of these incidents and to assess the cause or problem in each case. However, there is no doubt that at the instant each occurred it was not so easy or obvious, and the crews were faced with the stark realisation that an accident could be only a matter of feet away.

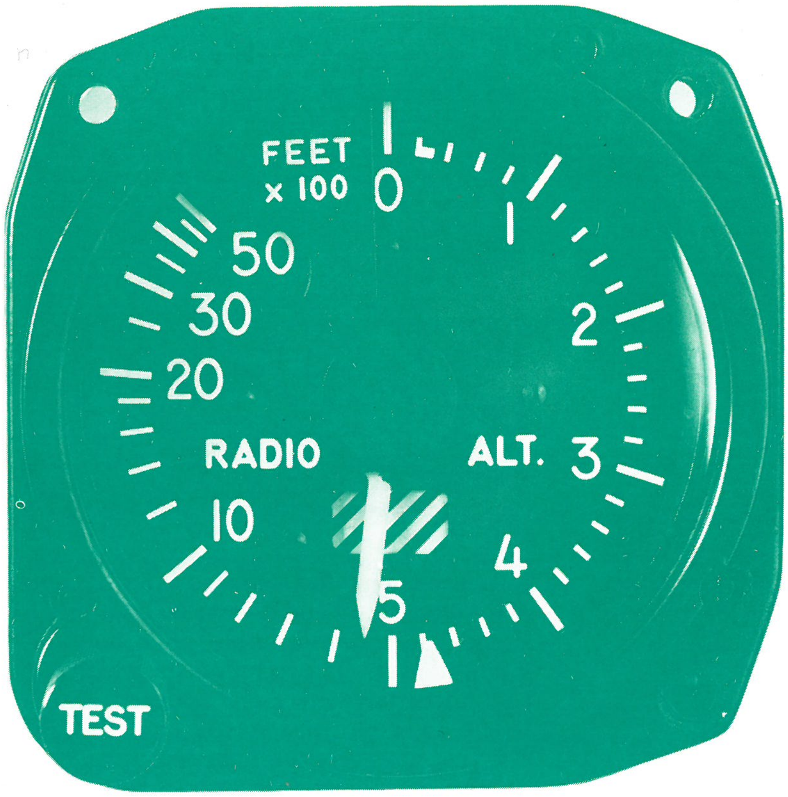
The major operational difference between the barometric and radio altimeters is that the former indicates barometric height above a selected pressure level while the latter measures the distance between the aircraft and the terrain. This difference can sometimes be confusing when, for example, the barometric altimeter indicates an increasing height whilst the radio altimeter is decreasing because the terrain over which the aircraft is flying is rising at a greater rate than the aircraft is climbing. Also, we use the radio altimeter on some of our aircraft for low-level terrain following – something it was not originally designed for – and whilst it gives us a good indication of our present vertical position it tells us nothing of the topography ahead of us.

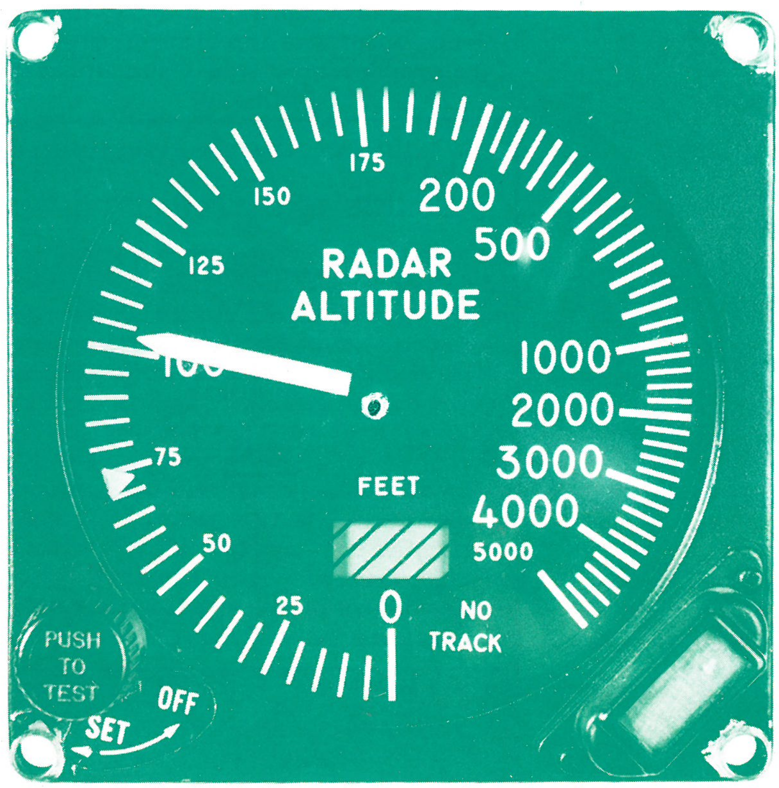
Radio altimeters employ one or other of two electronic ranging techniques: pulsed transmissions in which height (range) information is derived from the elapsed time between a single pulse being transmitted and received, or frequency modulated carrier wave (FMCW) in which height is determined from the frequency difference between the transmitted and received wave measured at the same time. In the past, pulse systems tended to be used at high altitude while FMCW was the preferred technique when greater accuracy at low level was the main consideration. FMCW systems, however, suffered from interference between transmitter and receiver while pulse systems had the advantage that the receiver was switched off during transmission. Recent developments, such as tracking the edge of the transmitted pulse, have allowed pulsed systems to be used at low altitude, although this has meant that pulse systems have become vulnerable to mutual interference. These characteristics are, of course, considered during development, and equipments and installations cleared for service use have been designed to overcome the inherent limitations. Nevertheless, difficulties can still arise when operational rôles or flight profiles are changed or when aircraft configurations alter. Usually the effects of such decisions are assessed in flight trials and any necessary modifications are subsequently developed.

When a radio altimeter indication causes aircrew to question its accuracy then it is usually because the equipment is faulty, it is being operated outside its limits or the aircraft isn't where the crew think it is.

Equipment Failures. Although, with the advent of low voltage solid state technology, modern avionics are becoming much more reliable, we still have a long way to go to produce a perfect system. Furthermore, most radio altimeters now in use were not originally specified as critical flight safety systems. While every effort is made to ensure that they are as reliable as possible, or at least fail safe, current designs are a compromise. All equipments are provided with failure warning indication and built-in test (BITE) facilities, but even so, it must be accepted that not all failures will be detected and indicated and the systems need positive monitoring. Many installations, particularly those intended for operation at low altitude, employ improved presentations through the head-up display, limit lights or audio warning systems. Indicating systems such as these undoubtedly make it easier to use the radio altimeter's height information, but they are not usually protected against failure. There is, therefore, a danger that too much reliance can be put on the warning system. Also, of course, while radio altimeters are usually capable of providing information about rate of change of height this is rarely used except in automatic flight systems. The cockpit displays must therefore be interpreted while the height is changing either because of flight conditions or because of terrain.

Equipment Limitations. Current radio altimeters suffer two main limitations: they can be used only in certain restricted height bands and secondly the aircraft must not manoeuvre outside defined limits if the altimeter is to continue indicating accurately. If an aircraft is flown above its radio altimeter's selected range then a height will be reached finally where the equipment will 'break lock'. Depending on the type of installation, height indication will then either remain at full deflection, wander on scale or reduce to zero (or any combination of these) until the height returns to within lock-on range once more. Contrary to popular belief, radio altimeters are not realistically limited in maximum height by virtue of their pulse recurrence frequency (prf) or frequency sweep cycle time. They cannot, for example, lock on to a second pulse or frequency sweep from their own transmitter when operated outside their selected range. Aircraft manoeuvres that exceed the installation's roll and pitch limits can result in the radio altimeter indicating a height greater than true. However, the roll and pitch limits are generally quite generous; for instance, the AN/APN 171 fitted to Canberra PR7,





Hercules C1 and W2, Nimrod MR1, R1 and MR2, Puma HC1 and Wessex HC2 and HC4 aircraft, is accurate within pitch and roll limits of ±30°. The technique by which roll and pitch parameters are achieved is different in both the pulsed and FMCW systems; however, the following somewhat simplified explanation may be of interest. If the beamwidth of a particular equipment is 60° then it will sense and indicate the nearest terrain within the beam. This is illustrated by Figs 1 to 4 (these show the roll plane only but the same is true for pitch) when x is the minimum height sensed and indicated and y is the true height of the aircraft above the ground. Figs 1 and 2 illustrate how the radio altimeter is able to indicate true height (when x = y) up to a roll angle of 30°.

However, with reference to Fig 2, it is important to remember that the radio altimeter is mounted in the fuselage but the wing tip could be much closer to the ground. This may not present a problem for the pilots of the smaller combat type of aircraft but it

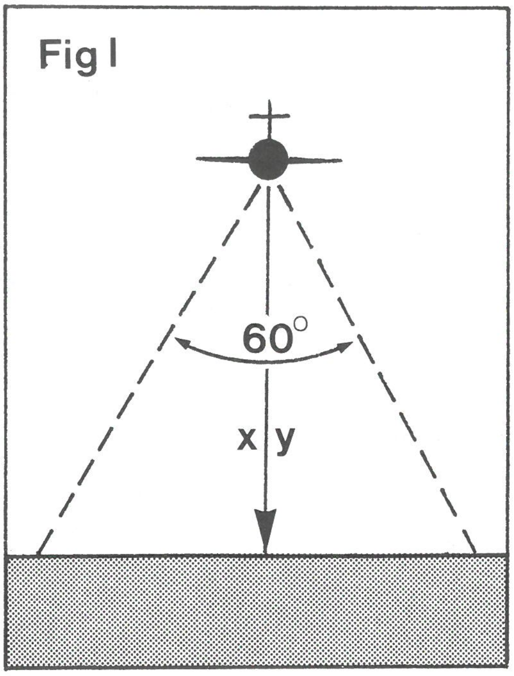


Fig 1

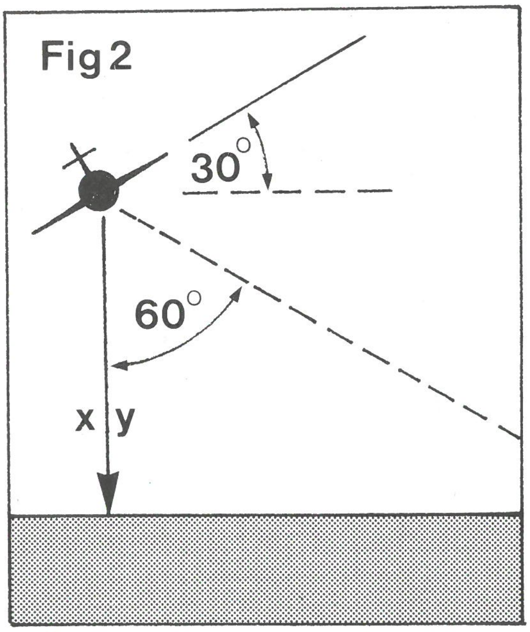


Fig 2

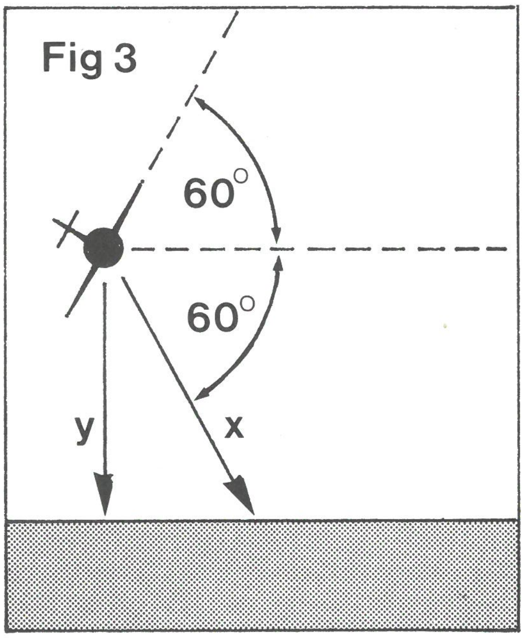


Fig 3

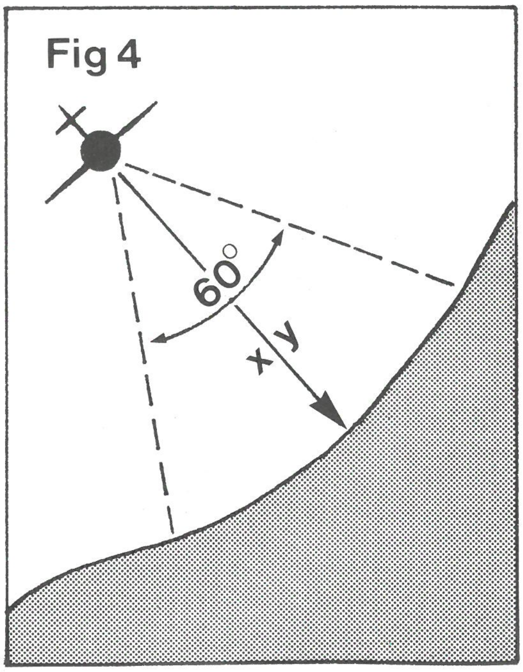


Fig 4

could be a significant factor with larger aircraft when flying very low. In a 30° bank the wingtip of a C130 aircraft is 23 ft closer to the ground than the fuselage (21 ft for a Nimrod). Fig 3 illustrates the danger of relying on the indicated height if the aircraft is manoeuvred in excess of 30° of roll where $x > y$. Fig 4 shows that, even if more than 30° of bank is flown, an accurate distance from the terrain can still be indicated if the relative angle between the aircraft and the slope of the terrain is within 30°.

Mistaken Location. Aircraft sometimes end up over terrain different from that over which the pilot believes he is flying. An analysis of world-wide civil jet aircraft accidents during the period 1959 to September 1976 revealed that of the 214 aircraft which were destroyed, 111 were as a result of 'controlled flight into terrain'; it must be assumed that in the vast majority of these accidents the crews did not either know or believe their true position and crashed into the ground as a consequence. The recent Boeing 737 crash at Tenerife is an example. If a pilot feels sure of his position (but is mistaken) and the height readings do not correspond to those which he expects relative to the terrain, then he is likely to doubt the accuracy of the radio altimeter rather than his location. The danger is obvious.

The lesson and message are clear: if a radio altimeter reading gives cause for concern then believe it, react accordingly and analyse afterwards.

In summary, it is not always appreciated that a radio altimeter only measures the height of an aircraft above the ground directly below it. It cannot predict the terrain ahead of the aircraft, and indeed is unable to detect a slope. At high speed and low level, terrain and altitude can change rapidly and there is little time for action. Radio altimeter height must, therefore, be supplemented by information derived from other sensors such as radar or the eyeball, if it is to give meaningful information. Ground proximity warning systems (GPWS), which mix absolute height and rate of change of information, are used in some civil applications. The current systems are designed for relatively stable flight paths and are considered to have serious limitations for military use. However, a new radio altimeter system has been proposed for low level operations and a future trial is planned.

Selected INCIDENTS

LIVE EJECTION SEAT

"I was allocated the aircraft for a night sortie. During the pre-flight safe for parking check I discovered that the port ejection seat was live with both guillotine and seat pan safety pins stowed in the stowage block."

Wing Commander Spry says:

The previous pilot was distracted by an RT call whilst he was doing his after landing checks and forgot to put the pins in the seat. After engine shut down a ground crewman replaced the canopy jettison and face screen pins but neither he nor the pilot noticed that the seat was unsafe. Moreover, another technician missed the vital check when he carried out an AF/BF servicing, including night flying checks, at the end of the day's flying.

The lesson is clear: ejection seat pins are still being forgotten and it is up to both aircrew and groundcrew to check and double check that ejection seats are safe. If we don't, then we will have another accident and someone may get killed or maimed.

STRIPPER HAZARD WARNING

"It has been brought to our attention that item 33D/2240473 floor polish stripper is of a hazardous nature. Some strong alkaline solutions, such as concentrated stripper, will rapidly dissolve aluminium with liberation of hydrogen gas. The concentrated stripper should only be removed from its plastic container when it is being diluted by pouring one part of the concentrated solution into 10 parts of water. Any normal cleaning utensil is suitable for this dilution. The concentrated stripper should never be decanted into aluminium containers. Future deliveries of stripper will include a hazard warning on the container."

Wing Commander Spry says:

Make sure this floor polish stripper is kept well away from aircraft.