Potential Impacts of 5G on Radio Altimeters during Aircraft Operations

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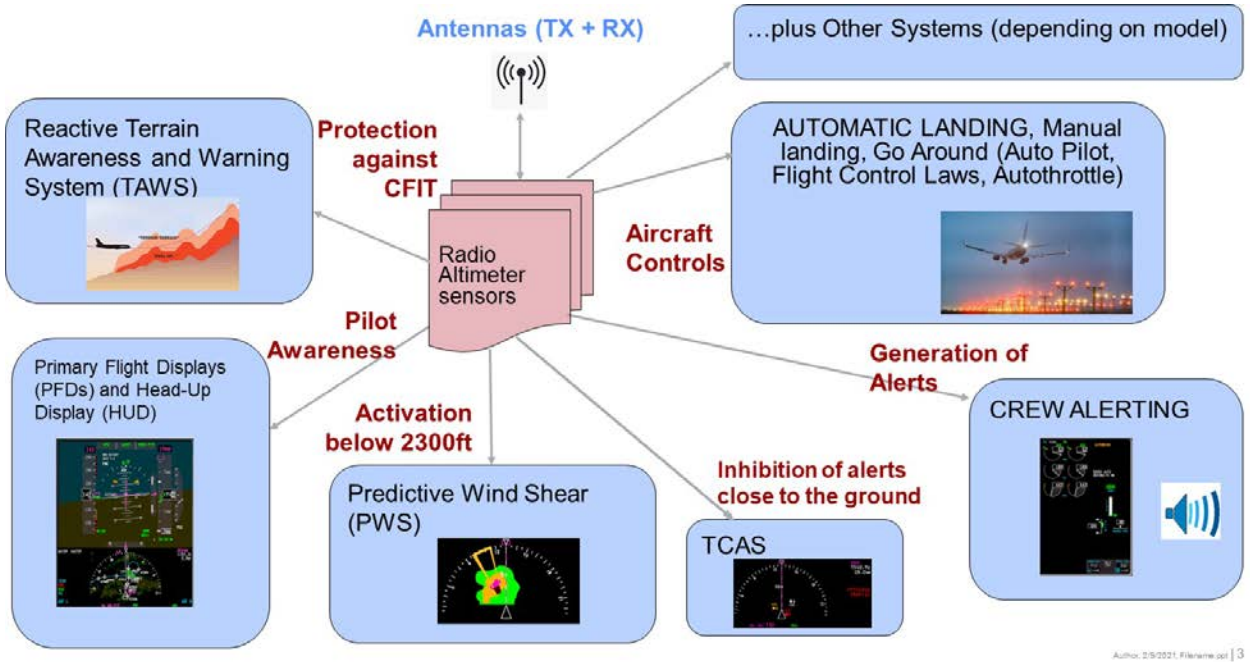
Altimeter Spectrum Basics

- Application of the Aeronautical Radio Navigation Service (ARNS)
- 4200-4400 MHz is allocated to ARNS, FN 5.438 identifies the band for altimeter use
- The ONLY sensor that provides Height Above Terrain
  - Vital for:
    - Flight Crew Situational Awareness
    - Input to many safety of life systems on board

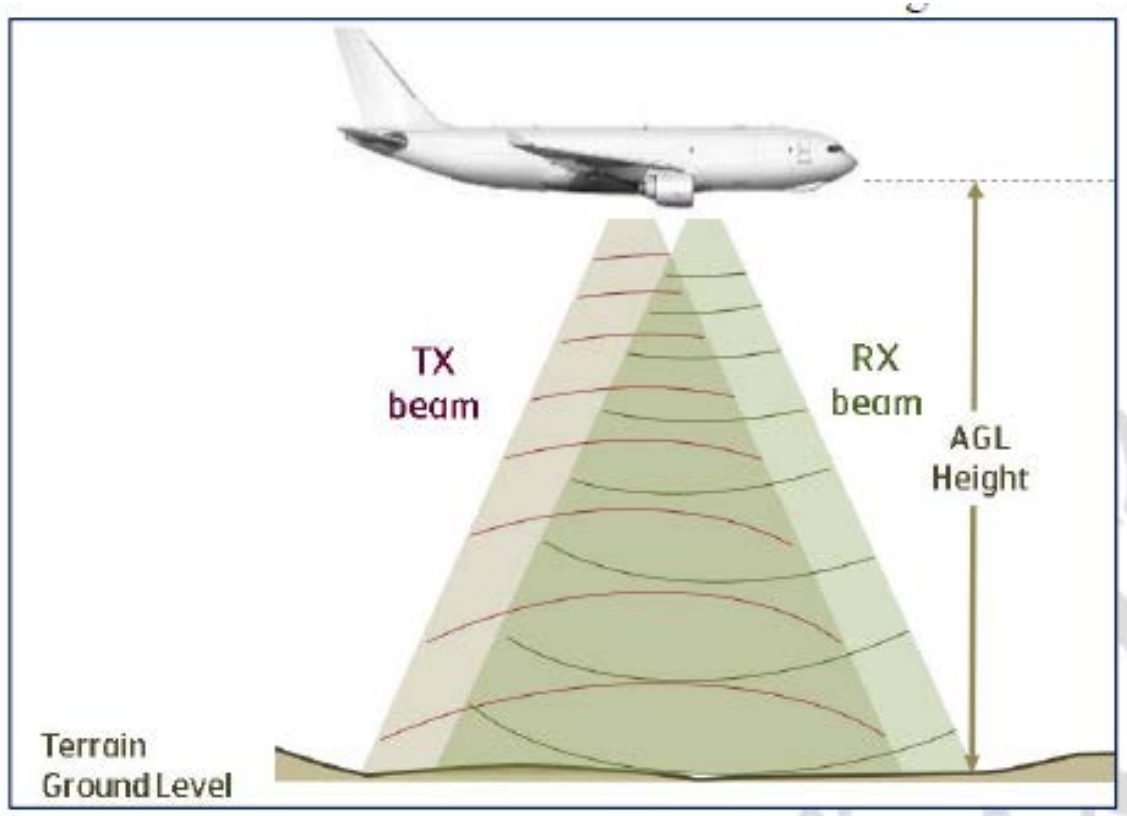
Altimeter System Contributions

- Radio Altimeter provides critical data for:
  - Terrain Awareness and Warning system (TAWS)
  - Predictive Windshear (PWS)
  - Traffic Collision Avoidance System(TCAS)
  - Automatic Landing
  - Automated systems
    - Flare
    - Autothrottle
    - Thrust Reverser Deployment



The Radio Altimeter

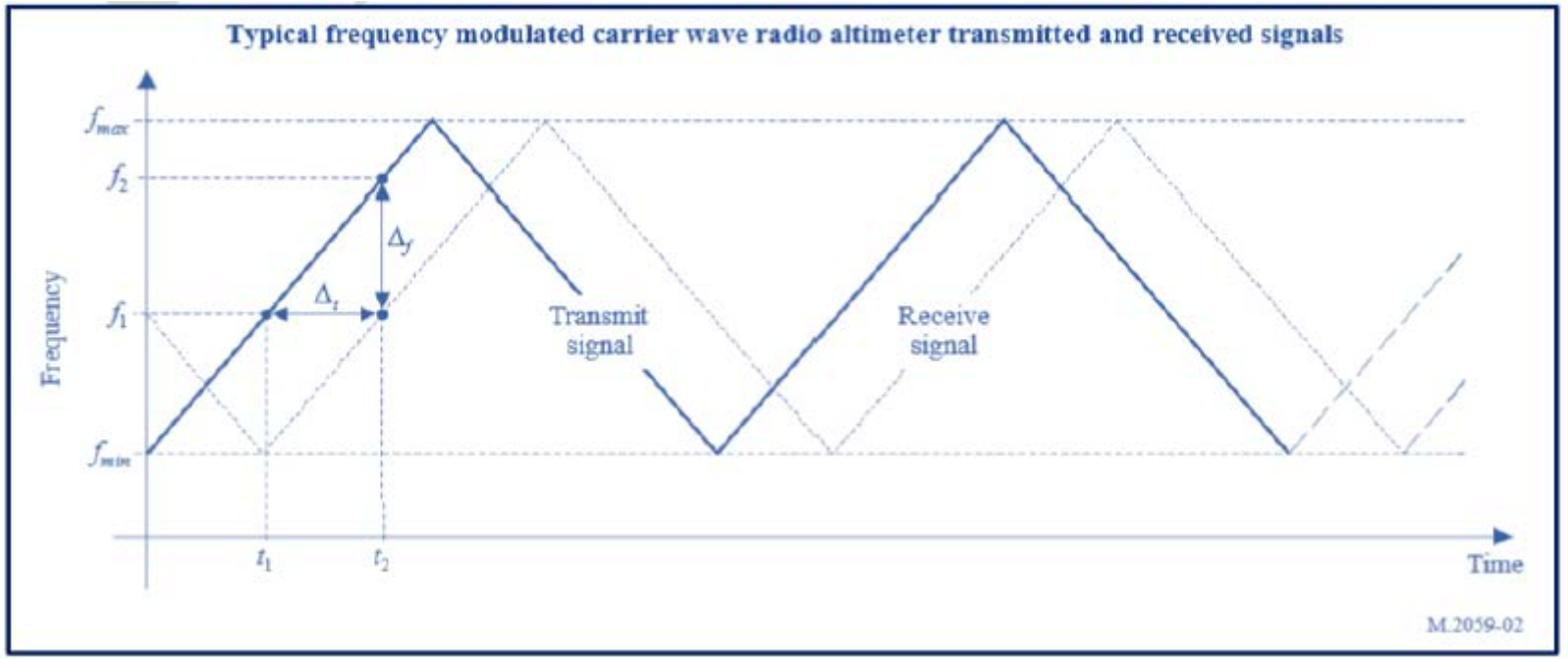
- Typical Characteristics in Recommendation ITU-R M.2059
- Depending on aircraft design, there may be up to 3 radio altimeters installed
  - All operate (Tx/Rx) simultaneously
- Due to the importance, the altimeter is included in the minimum equipment list for passenger aircraft
- Design Assurance Level (DAL) A – where software/hardware failure would cause and/or contribute to a catastrophic failure of the aircraft flight control systems



Types of Altimeters

- Two General ‘types’ of altimeters
  - FMCW – Frequency Modulated Carrier Wave (or Linear Frequency Modulation Continuous Wave - LFMCW)
  - Pulsed Modulation

A vast majority of civil transport aircraft (passenger and cargo)



- Not a fixed frequency
- Sweeps the bandwidth
- Altitude is determined by the difference in frequency and time
- Robust and reliable design

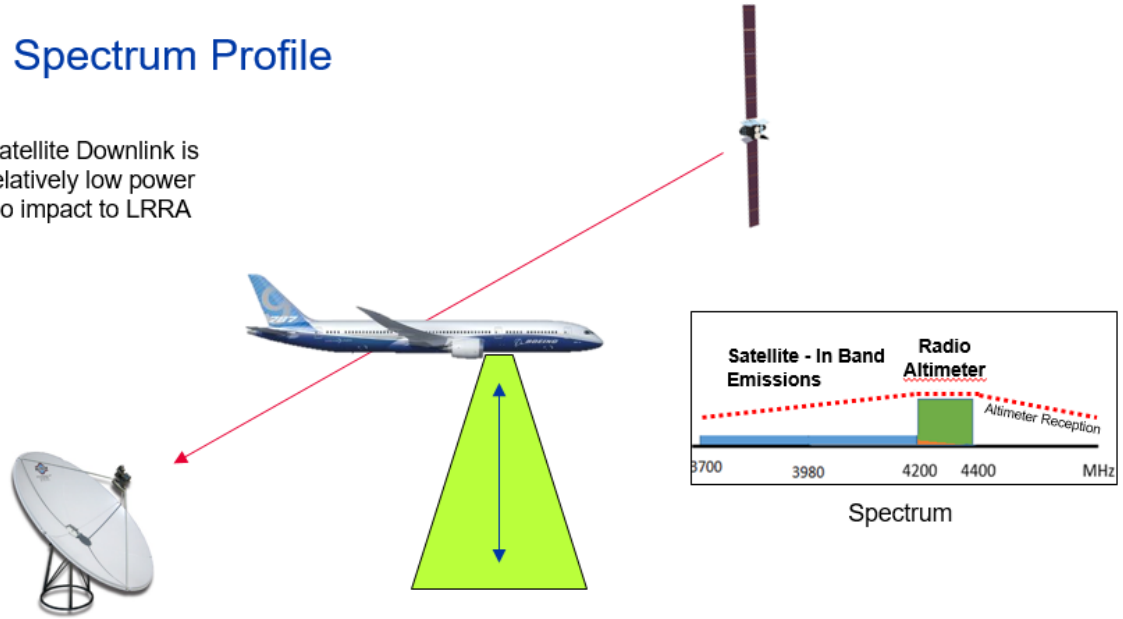
Changes to Spectrum

- Last major altimeter standard update was in 1980
- Decades of reliable service
- Nearby spectrum users primarily satellite downlink
- But…..spectrum allocations are not static
- Beginning around 2015, Mid-Band or C-Band spectrum nearby the altimeter and previously allocated to satellite downlinks has been allocated to 5G (IMT)

Drastically New RF Environment

Old Spectrum Profile

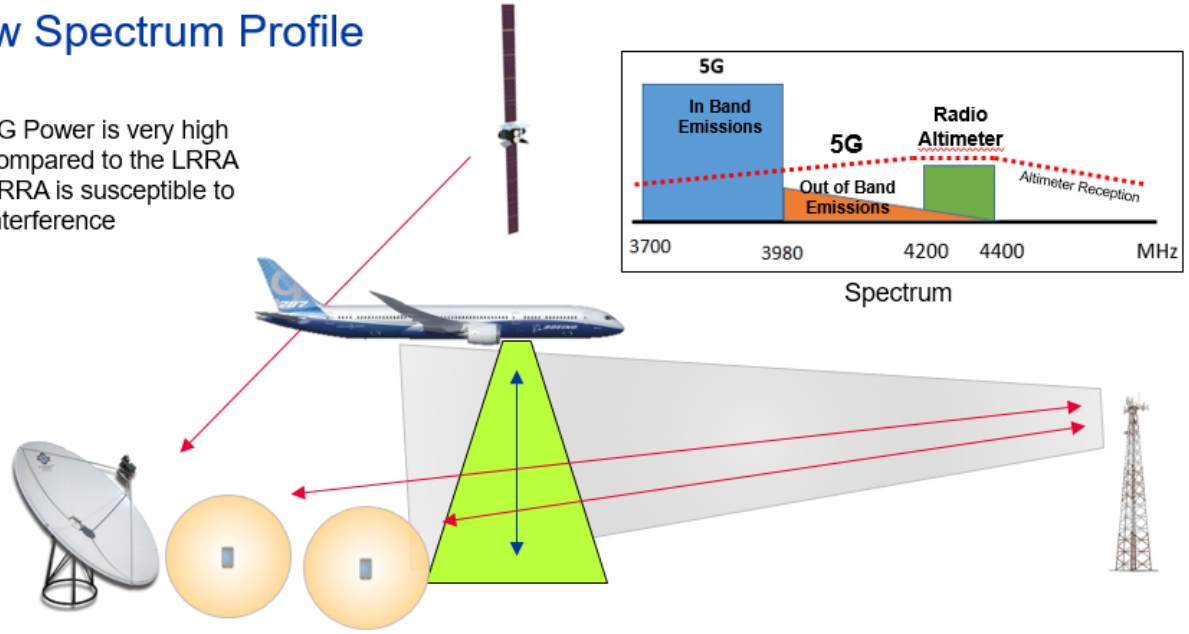
- Satellite Downlink is relatively low power
- No impact to LRRA



Spectrum

New Spectrum Profile

- 5G Power is very high compared to the LRRA
- LRRA is susceptible to interference



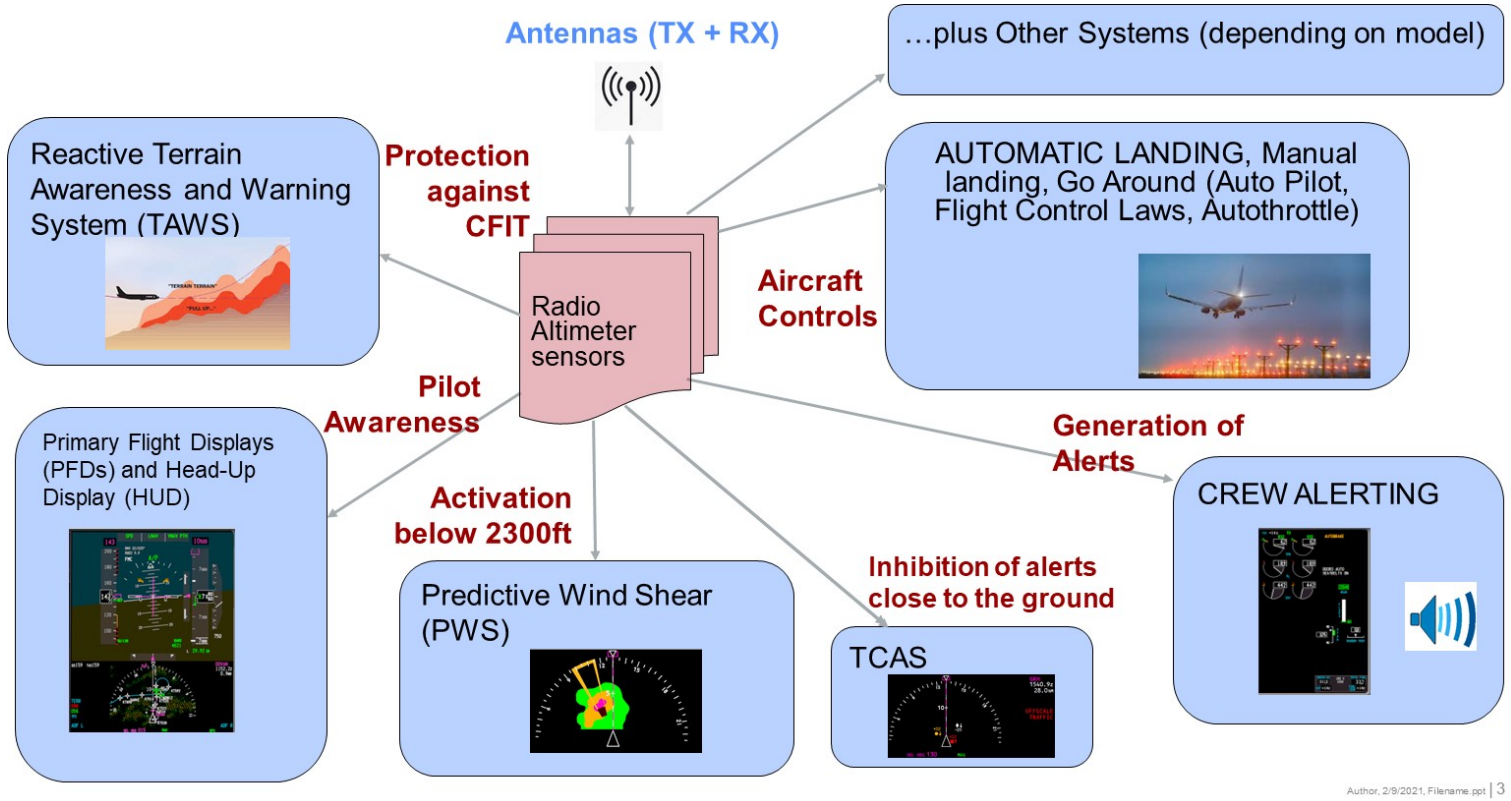
Spectrum

The New Spectrum Environment

- Altimeters were not designed to fully withstand the high levels of terrestrial interference in adjacent or nearby bands.
- In response to the US FCC 5G allocation in 3.7-3.98 GHz RTCA formed a task force to asses the impact of wireless broadband operations and issued a report in October 2020
  - Identified potential risks to altimeters caused by 5G base station interference

Interference Impacts on Aircraft Operation

- All systems that use altimeter data are impacted
- Crew Situational Awareness:
  - Impacts Nominal Crew Operation
  - Impacts Off-Nominal Crew Operation



Potential Results

- Controlled Fight Into Terrain (CFIT)
  - Loss of aircraft, loss of life
- Unreliable Safety Systems
  - Systems that crews expect to work may not
- Loss of stopping authority on landing – Runway Overrun

Hazard Severity Classifications

Severity	Allowable Occurrence Per Flight Hour
Minor	1×10^{-3}
Major	1×10^{-5}
Hazardous/Severe Major	1×10^{-7}
Catastrophic	1×10^{-9}

Hazards

Radar Altimeter Failure	Operational Impact	Flight Phase	Severity
Undetected Erroneous Altitude	Just prior to touchdown, the aircraft performs a flare maneuver to avoid a hard landing. The flare may be performed manually by the flight crew, using auditory callouts of radar altimeter readings, if sufficient visibility is available. In low-visibility conditions, the flare may be controlled by an autoland function. Erroneous radar altimeter readings in either case can result in the potential for CFIT with little or no time for the flight crew to react.	Landing – Flare	Catastrophic
Undetected Erroneous Altitude	Erroneous input to the AFGCS affects aircraft attitude commands and altitude, as well as flight control protection mechanisms	All Phases of Flight	Catastrophic

Hazards (Con't)

Radar Altimeter Failure	Operational Impact	Flight Phase	Severity
Unanticipated NCD[1]	Undetected loss of PWS display to flight crew, preventing awareness of wind shear impact to vertical profile in front of the aircraft	Landing	Hazardous/ Severe Major
Unanticipated NCD	Undetected loss of TCAS/ACAS inhibition near the ground, leading to potential erroneous descent advisory alert and associated possibility of CFIT in low-visibility conditions	All Phases of Flight	Catastrophic
Undetected Erroneous Altitude	Erroneous triggering of TAWS reactive terrain avoidance maneuver, forcing mandatory response from flight crew and leading to potential traffic conflicts in surrounding airspace	Approach, Landing, Takeoff	Major

[1]The term NCD is used to indicate conditions in which the radar altimeter cannot make an altitude determination

Hazards (Con't)

Radar Altimeter Failure	Operational Impact	Flight Phase	Severity
Unanticipated NCD	Aircraft landing guidance flight control laws violated leading to unnecessary missed approach and go-around, jeopardizing safety of surrounding airspace	Approach, Landing	Major
Unanticipated NCD	Loss of capability to perform approach and landing in low-visibility conditions (Category II/III approach), leading to unnecessary diversion and jeopardizing safety of surrounding airspace	Approach, Landing	Hazardous/Severe Major
Unanticipated NCD	Loss of capability to warn flight crew in case of excessive aircraft descent rate or excessive terrain closure rate (TAWS Mode 1 and 2 alert protection not active)	All Phases of Flight	Major

Hazards (Con't)

Radar Altimeter Failure	Operational Impact	Flight Phase	Severity
Unanticipated NCD	Loss of capability to warn flight crew of potentially dangerous loss of height after takeoff (TAWS Mode 3 alert protection not active)	Approach, Landing	Major
Unanticipated NCD	Loss of capability to warn flight crew of potentially dangerous aircraft configuration—e.g. landing gear, slats, flaps—based on height above terrain (TAWS Mode 4 alert protection not active)	Landing	Major
Unanticipated NCD	Loss of capability to warn flight crew that aircraft is dangerously below glide path during precision instrument approach (TAWS Mode 5 alert protection not active)	Landing	Major

- Q&A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