Questions and Answers from RTCA Webinar:

Interference Risk on Radar Altimeters from Planned 5G Telecommunication Systems

Webinar Question	Answer
Would like to hear exactly what the 5G interference will DO: will it result in erroneous data, or a false Zero height indication, or a No Computed Data indication? Is there any work-around by having multiple radar altimeters? How about having the radar altimeters tuned to (slightly) different frequencies? Are there any anti-jam schemes that can be applied to radar altimeter hardware to mitigate the effects of the interference?	The actual interference impacts may vary based on the specific radar altimeter model, but observations in the AVSI testing included increased altitude output noise, erroneous altitude readings (off by hundreds or thousands of feet), and loss of track (reporting No Computed Data). Because the RF interference in this case is external to the aircraft and the radar altimeter antennas in a multiplex installation will generally be close to each other, it is anticipated that any harmful interference would be highly likely to present as a common-mode failure for all radar altimeters onboard. Regardless of the specific center frequency used by a given radar altimeter, generally the receive bandwidth will cover a very large portion of the 4.2 - 4.4 GHz band (more than 100 MHz). Further, the rejection of interference from outside of the 4.2 - 4.4 GHz band is not likely to depend on the tuned center frequency of the radar altimeter. The best mitigation solution is to limit the amount of RF power that is exposed to the mixer in the radar altimeter receiver. If this power level is too high, then there are few options for mitigations in the IF or baseband signal domains. This power could theoretically be limited by means of additional band-pass filtering in the receiver front-end, but implementing this into a radar altimeter design is not necessarily straightforward and may introduce other performance limitations. Notice also that adding a band-pass filter needs 2 years for certification, and several additional years for industrialization and retrofit in airlines.
What is the maximum power transmitted by the radio-altimeter?	This may vary across different radar altimeter models, but FMCW altimeters generally have continuous output power in the range of 100 mW to 1 W, and pulsed altimeters generally have peak output power in the range of 1 W to 5 W.
Looks like other countries are getting closer to RADALT freq than the US proposes. Are they concerned? If not, why not?	Currently, the RTCA white paper was scoped to capture the operational environment and potential interferrence in the US using TSO'd Radar Altimeters. Further work may be done on additional scenarios including international environments and military radar altimeters. If requested, we are prepared to do additional testing.
How far away from 4,2-4,4 GHz is regarded as adjacent band in this case?	"Adjacent band" is somewhat of a misnomer which carries over from earlier proposals by the FCC which would potentially consider 5G operations nearly all the way up to the 4.2 GHz band edge. Other countries are considering 5G or other allocations much closer to 4.2 GHz as well. However, the work conducted by SC-239 and the tested performed by AVSI reveal that interference risks exist even with the proposed 220 MHz guard band.
Is it possible based this task group report to get conclusion that the 5G industry will require to restrict the base stations in a manner that will eliminate the radio altimeters effects on the airplanes?	RTCA does not have any information on what other entities may do with the work including other industries, US regulators or International Regulators. That question would be better asked of those entities.

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If the aircraft is moving at approach speed you will quickly move away from interference source meaning the persistence of event would be short. Wouldn't the RA recover?	In some scenarios the exposure time for the interference may be short (although in other scenarios, including approach scenarios depending on the relative geometry between the aircraft and base station). However, occurrences of just tens or hundreds of milliseconds could lead to erroneous output from the radar altimeter(s) or a complete loss of function. Further, recovery may not be instantaneous and may require several additional seconds after the interference subsides. These times are sufficient to produce detrimental effects to other aircraft systems which rely on the radar altimeter output, with possible severe safety implications. For example, the pilots could receive an erroneous warning from the TAWS, requiring an aggressive pull-up and climb maneuver in response. Or, during an autoland approach, erroneous radar altimeter output could cause an early flare maneuver or throttle retard before the aircraft has crossed the runway threshold, which could lead to a stall. There are some geometries that can cause persitent interferences like having a base station with a beam aligned with runway glide slope. In addition there is a particular scenario that cause the beam of the Base station to point constantly to the aircraft when the User Equipment (e.g phones) are left switched on during the landing. Such interferences steered fairly above the horizon has been analyzed in the report but is not mentioned in the conclusion because 5G stakeholders did not considered this case as a nominal/typical case.
Is there any change the FAA will require to adopt on the receivers on the airplanes to eliminate the interferences from the 5G transmitting?	RTCA does not have any information on what other entities may do with the work including other industries, US regulators or International Regulators. That question would be better asked of those entities.
The group didn't check the influence for the military airplanes (airspace) but is it possible it also effect this airplanes during takoff and descent ? (for military airplanes?)	Currently, the RTCA white paper was scoped to capture the operational environment and potential interferrence in the US using TSO'd Radar Altimeters. Further work may be done on additional scenarios including international environments and military radar altimeters. If requested, we are prepared to do additional testing.
Have you seen or conducted any testing on interference on Rad-Alt with on aircraft air-to-ground equipment such as the Gogo equipment?	Only the 3.7 - 3.98 GHz band was considered directly in the SC-239 study, which was allocated by the FCC for "Mobile, Except Aeronautical Mobile" use. This means that the band will not be usable for air-to-ground communications links such as Gogo. Currently Gogo uses 3G/4G systems in the 850 MHz band. This may be discussed in the framework of the new MOPS being created by RTCA SC-239 and EUROCAE WG-119.
What type of mitigation actions have been proposed?	Potential mitigations were outside the scope of the testing, analysis, and conclusions outlined in the RTCA White Paper.
Does receiver blocking mean that the function is lost only or could the Radio Altimeter also output erroneous values?	In the testing conducted by AVSI to support the SC-239 study, both loss of function (No Computed Data) and erroneous altitude outputs (in many cases off by hundreds or thousands of feet from the true altitude) were observed. The specific interference effects vary across different radar altimeter models.
As seen in the presentation, countries like Japan and China, for example, have already allocated frequencies near the Radalt band to other applications. What have they done to guarantee interoperability? Can the US learn from the experience of these other countries?	Currently, the RTCA white paper was scoped to capture the operational environment and potential interferrence in the US using TSO'd Radar Altimeters. Further work may be done on additional scenarios including international environments and military radar altimeters. If requested, we are prepared to do additional testing.
The 5G band and the RA band is separated by 220Mhz! If that isn't enough separation to ensure safety, is there a proposal to what would be desired	Based on the testing conducted by AVSI and the study performed by SC-239, interference risks still exist regardless of this guard band. Further, the data suggests that frequency separation alone is not sufficient to adequately mitigate these interference risks.
This makes Portable Electronic Devices (PED) look like child'play. So why are global RF-regulators plowing forward with this EMI; $$$$$$	RTCA does not have any information on what other entities may do with the work including other industries, US regulators or International Regulators. That question would be better asked of those entities.

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What are some of the mitigation efforts that RTCA is suggesting to the FCC?	Potential mitigations were outside the scope of the testing, analysis, and conclusions outlined in the RTCA White Paper.
Great presentation, thanks a lot, very clear and straight to the point. Question, does the ITU have a standing or a position on this whole discussion? (Maybe under their (ITU) MoC with ICAO...[)	We are not aware of a position by the ITU at this time.
Is the area of interference when overflying a base station narrow, i.e. would a Usage Category 1 aircraft cross this area very quickly? Could the time of interference be short enough to self-clear the NCD state relatively quickly, and can it be filtered at signal post-processing / FWS level?	Not necessarily. Depending on the relative geometry between the aircraft and base station, as well as the interference tolerance of the radar altimeter(s) in question, interference events may be very brief or persist for a longer duration. However, harmful interference events lasting just tens or hundreds of milliseconds may be enough to cause erroneous altitude output or loss of function of the radar altimeter(s), and recovery after the interference subsides may take several seconds. This is especially problematic since any harmful interference would be expected to be a common-mode failure across all radar altimeters on the aircraft in a multiplex installation. Any such erroneous output or loss of function could present a safety issue if it occurs during critical phases of flight due to how the radar altimeter output is consumed by other systems. For example, an erroneous reading on an autoland approach may initiate the flare maneuver or throttle retard early, before the aircraft has reached the runway threshold.
In your view, which would be the most effective means to mitigate the risks in sharing the RF spectrum with all users?	Potential mitigations were outside the scope of the testing, analysis, and conclusions outlined in the RTCA White Paper.
I understand that you are still working with FCC on mitigation requirements between flex and radio altimeters. What work is being done with other administrations - e.g., Japan which allows flex up to 4100 MHz, UK which allow low and med power flex up to 4200 MHz?	Currently, the RTCA white paper was scoped to capture the operational environment and potential interferrence in the US using TSO'd Radar Altimeters. Further work may be done on additional scenarios including international environments and military radar altimeters. If requested, we are prepared to do additional testing.
If filtering won't help for mid-band noise, what mitigation methods are being considered, if any, inside the aerospace industry alone? (without help from the FCC and FAA)	Filtering won't help only for the case of spurious emissions from 5G systems that land within the Rad Alt band.
Are there any expectations that pulse mode RADALTs, in general, are less or more susceptible to this phenomena?	There is little in a pulsed radar altimeter design that makes it inherently more or less susceptible to out-of-band interference than an FMCW altimeter design. However, pulsed altimeters can generally tolerate the inclusion of additional high-Q band-pass filters in the receive path better than FMCW altimeters can, with minimal impacts to other performance. Therefore, the issue may potentiall be easier to mitigate on pulsed altimeters than on FMCW altimeters when considering the blocking case, not for spurious 5G emissions within the Rad Alt band.
Have there been any tests for interference on military radalts? If not, do you think there would be interference?	Currently, the RTCA white paper was scoped to capture the operational environment and potential interferrence in the US using TSO'd Radar Altimeters. Further work may be done on additional scenarios including international environments and military radar altimeters. If requested, we are prepared to do additional testing.
New MOPS being drawn by RTCA in collaboration with EUROCAE expected to be published by October 2022. Realistically when do you expect the first units complying with this standard to be available for forward and retrofit?	While many of our members participate in development and certification on avionics, that type of timeline has not been constructed as part of the scope of the SC-239 white paper.
Do you regard blocking is causing more problem than the spruious emission falling within 4,2-4,4 GHz?	Based on the SC-239 study, the impacts of receiver blocking are more significant for all usage categories. However, for the case of spurious emissions within the Rad Alt band, filtering within the altimeter system is not an optiion.
Which options do exist to improve the tolerance to adjacent band interference for already fielded radio altimeters?	This has not yet been fully explored, and was outside the scope of the SC-239 study.

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Thanks for a very comprehensive and informative presentation! I see that for the future the standards will be adapted to cope with 5G interference risk. What are the examples of proposed mitigations you see fit for the in-service aircraft to cope with the 5G interference risk today before more robust RA systems become available?	Potential mitigations were outside the scope of the testing, analysis, and conclusions outlined in the RTCA White Paper.
The growth of Channel definition in 3GPP standrds (TS 36.104) and the actual implementation of these chanel in any country have a huge time lag (10+ years). I am tracking this pattern and believe that 3GPP channels are decade from actual implementation. Your thought on how much time Aviation industry has for standards change-over. Specically Ch#42 etc...	This has not yet been fully explored, and was outside the scope of the SC-239 study.
You have understandably approached this from a US perspective but it is a global problem. As you point out, the 5G interest in spectrum is hugely valuable and 5G has significant implications for technology and business outside aviation. So what do you think the aviation regulators be doing about this? And can we get the 5G/mobile comms industry to pay for their impact on our safety?	RTCA does not have any information on what other entities may do with the work including other industries, US regulators or International Regulators. That question would be better asked of those entities.
Do these interference challenges apply to the lower part of the C-band as well? Like 3,4-3,8 GHz?	The scope of the SC-239 study was limited to the U.S. implementation in the 3.7 - 3.98 GHz band, but the results suggest that at least for some radar altimeters, the frequency-dependent rejection roll-off is quite slow. Therefore, 5G implementations should also carefully consider the issue, even if a lower frequency band is used.
Which level of spurious emission was assumed - the limit valid in the US I assume, i.e. -13 dBm/MHz?	As noted in the SC-239 report, 5G base stations were assumed to have conducted spurious emissions of -20 dBm/MHz (based on inputs from mobile wireless industry engineers), and 5G user equipment was assumed to have conducted spurious emissions of -30 dBm/MHz (based on 3GPP standards). In both cases these assumptions are well below the -13 dBm/MHz limit in the FCC Order, but they are assumed to be the worst case actually realized in the 4.2 - 4.4 GHz band. It is important to note that the FCC Order makes no distinction between the out-of-band and spurious domains, so the relatively high limit of -13 dBm/MHz is set in lieu of defining an entire emissions mask.
Excellent presentation; both clear and comprehensive. Thanks to all who have put in the work. The threat to aviation safety is clear, as is the level of risk. It is always difficult to make safety arguments in cases like this where there are competing economic and political interests at the highest global levels. It appears that an advocate is necessary amongst those levels. What specific actions can be taken by individuals viewing this presentation to elevate SC-239 findings to a wider audience to protect these bandwidths? Thanks	If an individual is part of a organization who would be impacted by this issue, either as a passenger or as a manufacturer, engage with your organization to make sure they are aware of the issue and ask them to engage with the appropriate legislative affairs folks they work with. If an individual is acting on his own, I'd suggest writing your Senators and House of Representatives office to ask them to look into the issue.
What is the position of the telecom industry regarding the aspect of 5G spurious emissions into the radio altimeter band?	RTCA does not have any information on what other entities may do with the work including other industries, US regulators or International Regulators. That question would be better asked of those entities.

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Your report concluded that: the risk of harmful interference to radar altimeters cannot be adequately mitigated by the aviation industry acting alone. Your answer today is new radar altimeter MOPS. What can we expect from the telecom regulators ?	RTCA does not have any information on what other entities may do with the work including other industries, US regulators or International Regulators. That question would be better asked of those entities.
Did you prooftest the simulation method against actual 3G/4G emissions ? what results ?	3G/4G are established on other bands and the power levels are different.
What spurious emissions would protect radio altimeters? And would lower power flexible use protect radio altimeter from receiver blocking?	The results provided in the SC-239 report indicate that a conducted spurious emissions level of of -16 dBm/MHz or less is needed to protect Usage Category 1, -48 dBm/MHz or less to protect Usage Category 2, and -32 dBm/MHz or less to protect Usage Category 3. For the blocking case, absolute radiated power limitations may not be necessary -- for example, the radiated power could be limited above the horizon only, to prevent interference to aircraft. However, the extent to which the 5G interference may exceed the safe limits for Usage Categories 2 and 3 identified in the SC-239 report suggests that additional mitigations may be necessary on the aviation side for these cases.
Who would be liable if an accident was caused by 5G interference?	RTCA does not have any information on what other entities may do with the work including other industries, US regulators or International Regulators. That question would be better asked of those entities.
With the worst case scenario, was there an estimation of the probability of this occurring?	RTCA report did not rely on a probability approach in itself, it relies on Laboratory tests, 5G assumptions coming from 5G stakeholders and realistics margin.
What interference avoidance measures are being considered in countries with mobile operations above 4GHz, such as Japan or UK?	RTCA does not have any information on what other entities may do with the work including other industries, US regulators or International Regulators. That question would be better asked of those entities.
Would it be technically feasible to use the altitude returns from weather radars as a filter?	Using Weather radars is a far more difficult and long approach compare to updating the RA filter itself
Do 5G user devices on board transport category aircraft also pose a hazard? The white paper seems to limit these effects to Usage Category 2 and 3 aircraft.	The case of 5G user equipment onboard Usage Category 1 aircraft was evaluated in the study, but the interference remained below the safe limits. The 5G user devices effect are limited to Usage category 2 and 3 when it comes to the power emissions from this 5G user devices. However those 5G user devices can make the 5G Base Sattion to steer their main beam upward toward the aircraft. Such persistent aggresive interferences steered fairly above the horizon has been analyzed in the report but is not mentioned in the conclusion because 5G stakeholders did not considered this case as a nominal/typical case.
What will be the solution? If there will not be any LRU modifications?	Potential mitigations were outside the scope of the testing, analysis, and conclusions outlined in the RTCA White Paper.
What type,of mitigation do you anticipate the FCC and FAA will seek?	Potential mitigations were outside the scope of the testing, analysis, and conclusions outlined in the RTCA White Paper.
Spurious RA's noticed as the aircraft descended on initial approach, passing FL200 and lower. Investigation linked these occurrences to Digital Pagers, as they encountered sufficient RF signal strength environment passing the mid-level flow-control gates. The pager generated EMI that was intercepted by the Radar Altimeter system (RAs), causing a "blip" in the heretofore idle RAs. The RAs blip was handed off to the TCAS which generated a phantom RA. Crew reports lead to an update in the TCAS software to ignore these phantom RAs.	TCAS uses Radio Altimeter for the sole purpose to inhibit the TA or RA (Traffic Advisories or Resolution Advsisories) when the aircraft is too close to the ground. TCAS never uses the Radio Altimeter to generate any TA or RA. So this spurious RA (Resolution Advsisories) you are dealing with is due to other causes: e.g barometric altitude inaccuracy of the ownship aircraft or of the intruder aircraft.

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Is the interference mostly present during takeoff and landing at airports or is it also present en-route?	5G interference from base station are present below 7000 ft AGL: so take off, landing, approach,SID and STAR. It is not expected to have 5G interference from base station when the aircraft is en-route.
Garmin is selling a RA they call the GRA 55. It seems to be a DSP architecture which would be amenable to implementing a bandpass filter? Are there others that are based on a DSP? Homologation could proceed on the basis of "similarity"?	All Radar Altimeters considered as part of the AVSI study have TSOs. Specific technology performance of specific brands of Radar Altimeters are outside the scope of the white paper.
What do the aviation community recommend that the FCC and other regulators do? When will a recommendation be available?	Potential mitigations were outside the scope of the testing, analysis, and conclusions outlined in the RTCA White Paper.