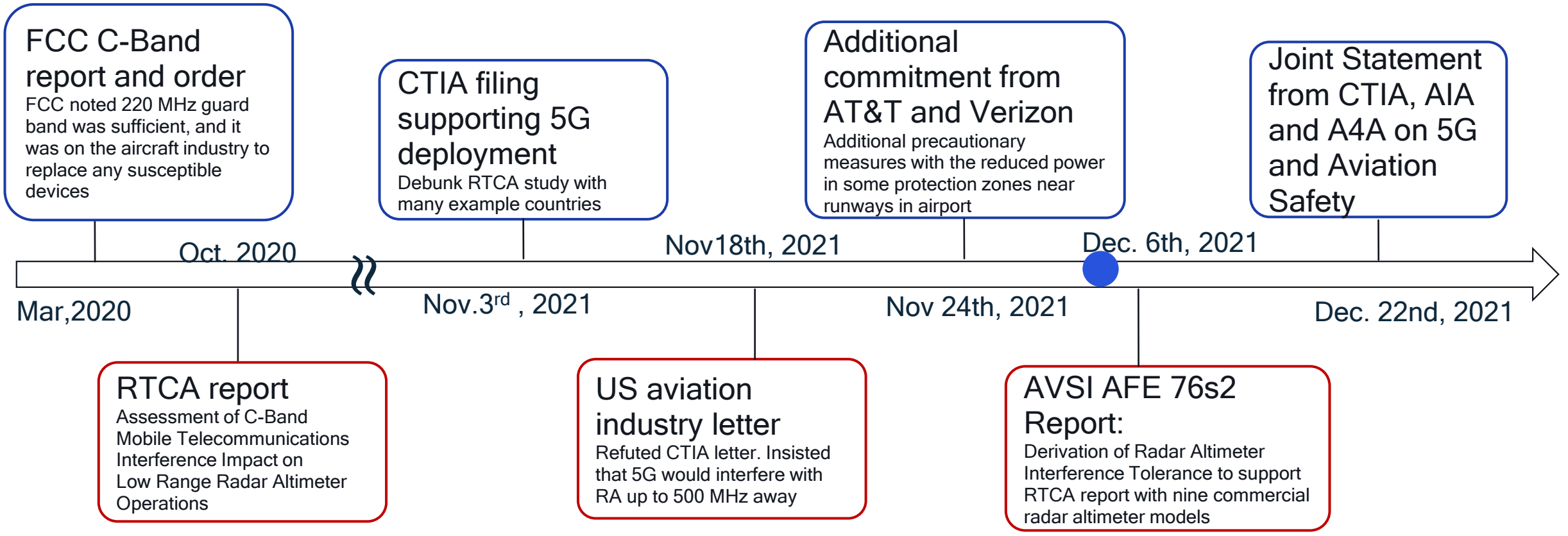
Jan. 11th, 2022

Qualcomm

Coordination Progress of C-Band Mobile Interference to Aircraft Radio Altimeters in U.S.

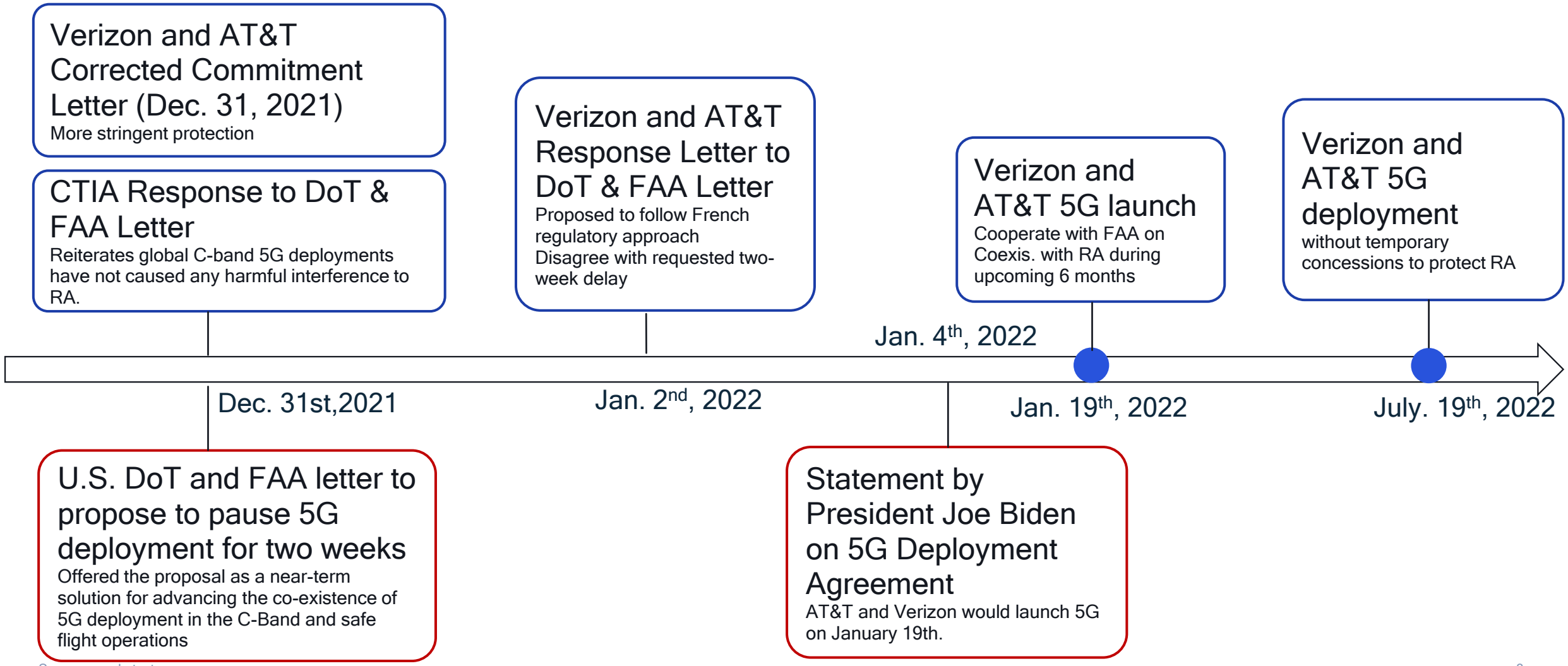
Information Sharing: Summary based on public information

Events of C-Band interference to Radio Altimeter in U.S.



Dec. 5th, 2021: Original 5G C-band deployment launch time. Postponed to January 5th per US government's request, and now deployments expected in mid-January, following further discussions noted on next page.

Events of C-Band interference to Radio Altimeter in U.S. (cont.)



Source sample text

Background

- Since October of 2021, the FCC and FAA (Federal Aviation Administration) had been in intense talks regarding 5G-friendly airwaves in the C-band (3.7-3.98 GHz) to air travel.
- FCC C-Band Report & Order noted that a 220 MHz guard band was sufficient to protect radio altimeters and that it was on the aircraft industry to replace any susceptible devices. (March 2020)
  - Paragraph 395. We agree with T-Mobile and Alion that the AVSI study does not demonstrate that harmful interference would likely result under reasonable scenarios (or even reasonably "foreseeable" scenarios to use the parlance of AVSI). We find the limits we set for the 3.7 GHz Service are sufficient to protect aeronautical services in the 4.2-4.4 GHz band. Specifically, the technical rules on power and emission limits we set for the 3.7 GHz Service and the spectral separation of 220 megahertz should offer all due protection to services in the 4.2-4.4 GHz band. We nonetheless agree with AVSI that further analysis is warranted on why there may even be a potential for some interference given that well-designed equipment should not ordinarily receive any significant interference (let alone harmful interference) given these circumstances. As such, we encourage AVSI and others to participate in the multi-stakeholder group that we expect industry will set up—and as requested by AVSI itself. **We expect the aviation industry to take account of the RF environment that is evolving below the 3980 MHz band edge and take appropriate action, if necessary, to ensure protection of such devices.**
  - Both AT&T and Verizon spent billions of dollars to obtain swaths of these prime 5G airwaves at an FCC auction and initially planned to begin making use of them for wireless service in 3.7-3.8 GHz (400 MHz away from radio altimeters) starting Dec. 5, 2021. Wireless carriers, including AT&T and Verizon, paid over $80 billion for C-band spectrum—and have committed to pay another $15 billion to satellite users for early access to the spectrum.
- Previously, the carriers agreed to push back that date by a month following the FAA issuing a special airworthiness information bulletin warning operators and aircraft and radio manufacturers about possible interference, particularly in cases involving radio and radar altimeters.

4.2 GHz - 4.4 GHz Radio Altimeter

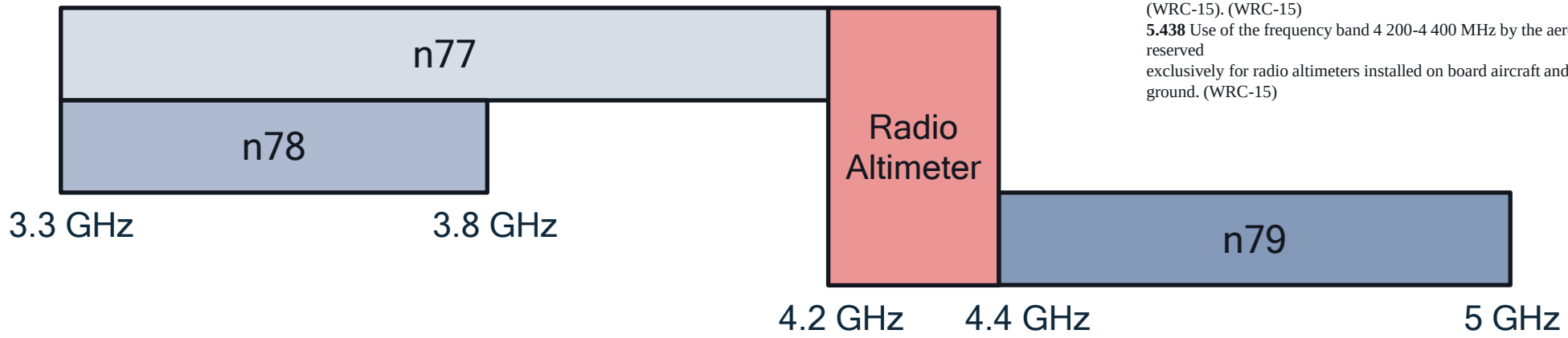
4.2 – 4.4 GHz is globally allocated to aeronautical radionavigation

- Radio Altimeter: ITU-R recommendation M.2059 (02/2014)
  - Title: Operational and technical characteristics and protection criteria of radio altimeters utilizing the band 4200 -4 400 MHz
  - The basic function of a radio altimeter is to provide accurate height measurements above the Earth surface with a high degree of accuracy and integrity during the approach, landing, and climb phases of aircraft operation representing a wide variety of reflectivity.
  - The radio altitude is computed from the time interval a signal, originating from the aircraft, is reflected from the ground. Radio altimeters designed for use in automated landing systems are required to achieve an accuracy of 0.9 m.
  - There are two types of radio altimeters in use today. One type utilizes Frequency Modulated Continuous Wave (FMCW) modulation, the second utilizes pulsed modulation.

Allocation to services		
Region 1	**Region 2**	**Region 3**
3 600-4 200 FIXED FIXED-SATELLITE (space-to-Earth) Mobile	**3 600-3 700** FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.434 Radiolocation 5.433	**3 600-3 700** FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile Radiolocation 5.435
	3 700-4 200 FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile	
4 200-4 400	AERONAUTICAL MOBILE (R) 5.436 AERONAUTICAL RADIONAVIGATION 5.438 5.437 5.439 5.440	
4 400-4 500	FIXED MOBILE 5.440A	
4 500-4 800	FIXED FIXED-SATELLITE (space-to-Earth) 5.441 MOBILE 5.440A	

5.436 Use of the frequency band 4 200-4 400 MHz by stations in the aeronautical mobile (R) service is reserved exclusively for wireless avionics intra-communication systems that operate in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution 424 (WRC-15). (WRC-15)

5.438 Use of the frequency band 4 200-4 400 MHz by the aeronautical radionavigation service is reserved
exclusively for radio altimeters installed on board aircraft and for the associated transponders on the ground. (WRC-15)



RTCA Study Report

October 7, 2020

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- RTCA Special Committee 239 (SC-239) formed a 5G Task Force in April 2020 to lead this study effort as a multi-stakeholder group with open participation from the interested public.
- Using technical information supplied by the mobile wireless industry and radar altimeter manufacturers, this report provides a quantitative evaluation of radar altimeter performance regarding RF interference from expected 5G emissions in the 3.7–3.98 GHz band, as well as a detailed assessment of the risk of such interference occurring and impacting aviation safety
  - This process included testing of many representative radar altimeter models to empirically determine their tolerance to expected 5G interference signals;
  - the development of interference models and assumptions to predict the received interference levels across a wide range of operational scenarios, such that they may be compared to the empirical tolerance limits;
  - and a thorough study of multiple real-world operational scenarios for civil aircraft in which the presence of the expected 5G interference will result in a direct impact to aviation safety
- The RTCA study shows harmful interference to radio altimeters can occur, potentially impacting public safety, and requiring regulatory restrictions. The RTCA study focused only on the U.S. transmission characteristics permitted by the Commission
  - The extent of the RF interference is summarized by the worst-case exceedance of the safe interference limit of radar altimeters by expected 5G signals in the 3.7–3.98 GHz band: 14 dB for commercial transport airplanes, 48 dB for business, regional, and general aviation airplanes, and 45 dB for helicopters.
  - Further, the impacts are not only limited to the intentional emissions from 5G systems in the 3.7–3.98 GHz band, but also the spurious emissions from such systems within the protected 4.2–4.4 GHz radar altimeter band directly. In this latter case, the worst-case exceedance of the safe interference limit is 28 dB for business, regional, and general aviation airplanes, and 12 dB for helicopters.

https://www.rtca.org/wp-content/uploads/2020/10/SC-239-5G-Interference-Assessment-Report_274-20-PMC-2073_accepted_changes.pdf

CTIA filing to FCC

Nov. 3, 2021

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- Urge to ensure C-band 5G deployment. CTIA states that 5G has been deployed in the C-Band across the globe
  - Nearly 40 countries have already adopted rules and deployed hundreds of thousands of 5G base stations in the C-Band, such as Japan, EU (CEPT report 67, UK, France, Switzerland, Finland), Australia, South Korea, etc
  - If RTCA's claims were correct, commercial 5G base stations deployed across the globe would not meet aviation's purported "safe" interference tolerance threshold.
  - Live flight testing confirms C-Band 5G operations coexist today with radio altimeter operations
  - Successful deployments domestically and internationally below 3700 MHz are relevant to the discussion of aviation's claims
- CTIA created a website(https://www.5gandaviation.com/) responding to the aircraft industry's claims of interference. The website notes that C band mobile operations in other countries are not causing harmful interference to altimeters and that other systems closer in frequency to the 4.2-4.4 GHz radio altimeter band create much more noise inside the band

https://ecfsapi.fcc.gov/file/1103192305940/211103%20CTIA%20Ex%20Parte%20on%20C-Band%20International%20Deployments.pdf

US Aviation Industry Letter to FCC

Nov.18, 2021

Adobe Acrobat Document

- Representatives of the aviation industry argue that 5G operations in the C-Band will cause harmful interference to radio altimeters that operate up to 500MHz away.
- CTIA provides numerous examples of countries that have deployed 5G without causing harm to public and aviation safety. The deployments and associated power levels permitted are not consistent or the same as those in the U.S.
  - Australia, South Korea, Norway, United Kingdom, Canada, US Navy AN/SPN-43 radar system
- The incremental economic gain from deploying 5G in this single frequency band pales in comparison to the negative economic impact if all aviation were to stop flying or stop relying on the information provided by radio altimeters.

https://ecfsapi.fcc.gov/file/1119034580247/Aviation%20Industry%20Reply%20to%20CTIA%2011-19-2021.pdf)

Additional Commitments from AT&T and Verizon

November 24, 2021

- In November 2021, AT&T and Verizon proposed to commit for six months to voluntarily adopt “additional precautionary measures” aimed at curbing fears about forthcoming 5G wireless service concerns about possible interference from the wireless carriers’ deployments disrupting airplane safety, the two carriers announced in a joint FCC filing Wednesday.
- The two wireless carriers said “these commitments include additional steps to minimize energy coming from 5G base stations – both nationwide and to an even greater degree around public airports and heliports” and “should allay concerns about radio altimeter performance.”

Adobe Acrobat Document

https://ecfsapi.fcc.gov/file/11241848723664/2021-11-24%20ATT%20Verizon%20Letter%20FINAL.pdf

Additional Commitments from AT&T and Verizon (Cont.)

Nov. 24, 2021

- Limit C-band EIRP above the horizon for all 5G base stations to no more than the lesser of: (a) 62 dBm/MHz or (b) 48 + 20 × log10(1/sin(Θ)) dBm/MHz, where Θ is the elevation angle above the horizontal plane of the base station antenna.
- Limit C-band EIRP below the horizon for all 5G base stations to no more than 62 dBm/MHz.
- In addition, for all public use Airports with paved runways, the different limits of C-band PFD and EIPR power density are identified for the different areas.
- In addition, for all public use Heliports, limit C-band PFD to no more than -16 dBW/m2/MHz on the primary surfaces of helipads.

https://ecfsapi.fcc.gov/file/11241848723664/2021-11-24%20ATT%20Verizon%20Letter%20FINAL.pdf

AVSI AFE 76s2 Report Derivation of Radar Altimeter Interference Tolerance Masks

Dec. 6, 2021

- Aerospace Vehicle Systems Institute (“AVSI”) provided report “Derivation of Radar Altimeter Interference Tolerance Masks Volume I: Introduction, Test Procedures, and Fundamental Test Results. It was to support the Commission’s review of the findings of the report previously filed by RTCA, “Assessment of C-Band Mobile Telecommunications Interference on Low Range Radar Altimeter Operations”.
- They tested nine commercial radar altimeter models for their sensitivity to fundamental emissions in the 3700-3980 MHz band and spurious emissions in the 4200-4400 MHz band from 5G signals permitted under the FCC’s rules.
- AFE 76s2 was limited to black-box testing (i.e., testing a system without regard to its internal workings) of a limited number of RAs. This method of testing incorporates all the internal signal chain within the RA, including front end filters, homodyne or heterodyne detection, and signal processing, without detailed knowledge of any of the internal features, and assesses the very same output an aircraft must use to determine correct altimeter readings.
- The only component of the transmit-receive detect signal chain that was not incorporated in AVSI testing was the effect of antenna performance
- Test results can be found in the reports: https://www.fcc.gov/ecfs/search/filings?express_comment=0&limit=25&offset=25&proceedings_name=18-122&sort=date_disseminated,DESC

Joint Statement from CTIA, AIA and A4A on 5G and Aviation Safety

December 22, 2021

- Below is a joint statement from CTIA – the wireless industry association, the Aerospace Industries Association, and Airlines for America about our ongoing collaboration to find a data-driven solution and deploy 5G while preserving aviation safety. The wireless industry remains fully committed to launch 5G in the C-band on Jan. 5, 2022.
- “We are pleased that after productive discussions we will be working together to share the available data from all parties to identify the specific areas of concern for aviation. The best technical experts from across both industries will be working collectively to identify a path forward, in coordination with the FAA and FCC.
- “Our belief is that by working collaboratively in good faith on a data-driven solution, we can achieve our shared goal of deploying 5G while preserving aviation safety.”

U.S. Department of Transportation and FAA letter to AT&T and Verizon

December 31, 2021

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- Offered the proposal as a near-term solution for advancing the co-existence of 5G deployment in the C-Band and safe flight operations.
  - Commercial C-band service would begin as planned in January with certain exceptions around priority airports.
  - The FAA and the aviation industry will identify priority airports where a buffer zone would permit aviation operations to continue safely while the FAA completes its assessments of the interference potential around those airports.
  - Their goal would then be to identify mitigations for all priority airports that will enable the majority of large commercial aircraft to operate safely in all conditions. This will allow for 5G C-band to deploy around these priority airports on a rolling basis, such that C-Band planned locations will be activated by the end of March 2022, barring unforeseen technical challenges or new safety concerns.
  - Meanwhile, the FAA will safely expedite the approvals of Alternate Means of Compliance (AMOCs) for operators with high-performing radio altimeters to operate at those airports.
- DoT and FAA asked that AT&T and Verizon continued to pause introducing commercial C-Band service for an additional short period of no more than two weeks beyond the currently scheduled deployment date of January 5. During this time, the FAA will identify the priority airports, issue the required Notices to Air Missions (NOTAMs) and begin approving AMOCs. During this time, the FAA will review information relating to the size of the buffer zone around critical airports and will seek to reduce the size when safely able based on data from aviation manufacturers.

https://www.faa.gov/general/dot-and-faa-letter-att-and-verizon

CTIA Response to DoT & FAA Letter

December 31, 2021

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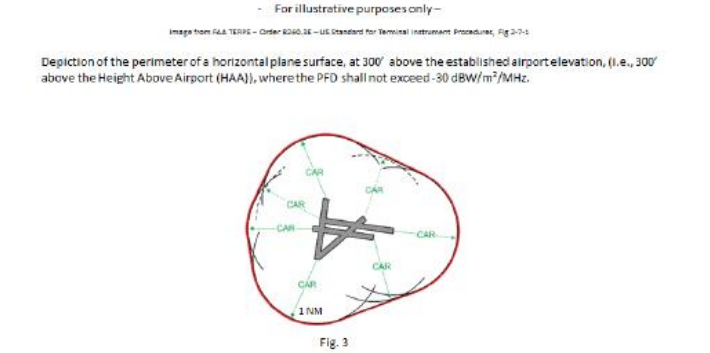
- In nations across the globe hundreds of thousands of 5G base stations are deployed in the C-Band today without harmful impacts to aviation operations–including in the 100 MHz segment (3.7-3.8 GHz) where C-Band 5G will be launched in the U.S. starting in January.
- Contrary to recent inaccurate assertions made by the aviation industry, a number of these countries have authorized power levels that are higher than those permitted under the Commission's rules, and the vast majority of nations with 5G deployments in the C-Band have no precautionary measures in place to ensure coexistence with aviation operations
- As the Federal Aviation Administration and European Union Aviation Safety Agency recently confirmed, there are no reported incidents of harmful interference to radio altimeters operating in the 4.2-4.4 GHz band, notwithstanding the thousands of flights operating within these nations every day.
- 5G is authorized today in numerous countries at power levels higher than what is permitted in the U.S., such as Denmark, Finland, and Ireland(with authorized power levels that are higher than what is permitted in the U.S.) as well as New Zealand, Romania, and Spain(with no regulatory upper bound at all).
- Both authorized and operational power limits in C-Band 5G networks across numerous countries would fail the aviation industry's purported "safe" threshold. These include Australia (which operates at 25,000x greater power than what the RTCA Report purports is "safe"), Japan (which exceeds the aviation purported "safe" level by 4,000), South Korea (which exceeds the aviation-purported "safe" level by 5,000), and the United Kingdom (which exceeds the aviation-purported "safe" level by 40,000)
- RTCA study has been fully debunked by CTIA. See Letters from CTIA to Marlene H. Dortch, Secretary, FCC, GN Docket No. 18-122 (filed Aug. 26, 2020; Oct. 27, 2020; Oct. 30, 2020; Nov. 17, 2020; Dec. 7, 2020; Mar. 4, 2021; Sept. 3, 2021; Nov. 3, 2021).

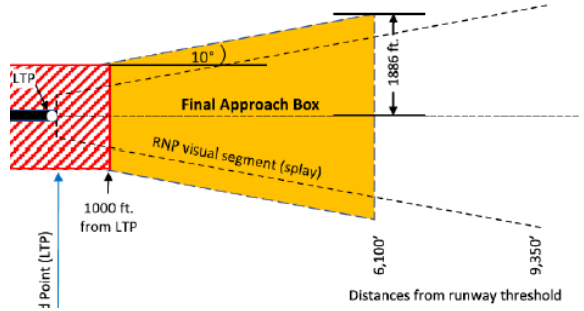
https://ecfsapi.fcc.gov/file/1231285079255/211231%20CTIA%20C-Band%20International%20Deployments%20Ex%20Parte%20Letter.pdf

Verizon and AT&T Corrected Commitment Letter
(Dec. 31, 2021)

AT&T and Verizon have voluntarily committed to additional precautionary measures for 6 months until July 5th, 2022

- (1) lower the power of C-Band transmissions in all areas above the horizon (as well as lowering power in rural areas below the horizon)
  - AT&T and Verizon have committed to limit power radiated below the horizon to no more than 62 dBm/MHz. In rural areas, this equates to about 50% less power than permitted by the C-Band Order.
  - As the angle above the horizon increases, AT&T and Verizon must ensure further reductions in emitted power. This condition will thus result in significantly lower emissions in navigable airspace than permitted by the C-Band Order.
- (2) effectively curtail C-Band operations in broadly defined areas near public airports.
  - The safeguards will yield low measured power levels on all airport surfaces, up to 300 feet above airports, and more than one mile from airport runways
  - Limit radiated power from 5G base stations to even lower levels when those base stations are located in line with airport runways. This commitment can apply to base stations located as far as 1000 feet from a runway
  - AT&T and Verizon also agreed to limit the height of C-Band antennas and the amount of radiated power for structures located in a designated “Final Approach Box”.
- (3) Limit radiated 5G power at public heliports.
  - In particular, they committed to ensure that measured power over the primary surface of all helipads is no more than -16 dBW/m2/MHz.





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https://ecfsapi.fcc.gov/file/12310305312507/2021.12.31%20ATT-VZ%20Committment%20Letter.pdf

Verizon and AT&T Response Letter to DoT&FAA Letter

January 2nd, 2022

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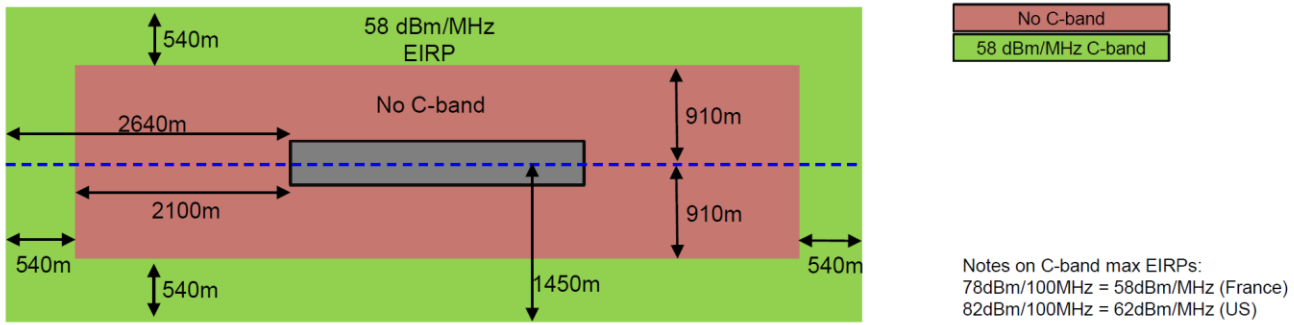
- For six months, until July 5, 2022, VZ and AT&T will adopt the same C-Band radio exclusion zones already **in use in France**, with slight adaptation to reflect the modest technical differences in how C-band is being deployed in the two countries.

  - That approach – which is one of the most conservative in the world – would include extensive exclusion zones around the runways at certain airports.
  - The effect would be to further reduce C-band signal levels by at least 10 times on the runway or during the last mile of final approach and the first mile after takeoff.
  - This is over and above the protections VZ and AT&T already committed to put in place around airports that were detailed in the letter to the FCC on November 24, 2021, as well as the corrected letter on Dec. 31st.



- France Exclusion Zone (red area): 910m x 2100m
- Power Reduction Zone (green area): Extends outside the exclusion zone an additional 540m on all four sides to accommodate 4 dB EIRP difference between France (78dBm/100MHz) and US (82dBm/100MHz)
- 540m is the calculated distance to generate 4 dB of free space loss

https://www.politico.com/f/?id=0000017e-1c36-dee4-a5ff-fe3e997f0000

Statement by President Joe Biden on 5G Deployment Agreement

January 4, 2022

My Administration is committed to rapid 5G deployment, while minimizing disruptions to air operations and continuing to maintain the world's safest airspace. Last night's agreement is a significant step in the right direction, and we're grateful to all parties for their cooperation and good faith. This agreement ensures that there will be no disruptions to air operations over the next two weeks and puts us on track to substantially reduce disruptions to air operations when AT&T and Verizon launch 5G on January 19th. For the last few months, my Administration has been convening technical experts at the FAA, the FCC, and from the wireless and aviation industries to discuss a solution that allows the expansion of 5G and aviation to safely co-exist, and I am pleased those efforts helped produce yesterday's agreement. I want to thank Secretary Buttigieg, FAA Administrator Dickson, and FCC Chair Rosenworcel, as well as AT&T and Verizon and airline industry leaders, for their tireless work to ensure that the expansion of 5G and aviation can safely co-exist.

https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/04/statement-by-president-joe-biden-on-5g-deployment-agreement/

GSA Questions on RTCA Study

January 11-12, 2022 @ECC PT1 #70

- 1.There is no clear basis for the criteria used to determine radio altimeter interference tolerance thresholds used in the report (Appendix A.4), especially when the requirements on the accuracy of estimated altitude specified in RTCA DO-55 are significantly relaxed compared to the criteria used in the report.
- 2.Moreover, these criteria and assumptions are even more stringent than the ones used by the aviation industry in their Wireless Avionics Intra-Communications (WAIC) studies in 2017; in particular:
  - a.6 dB cable loss are considered that were not present in WAIC studies, which means altimeter operating with a desired signal that is 6 dB lower.
  - b.6 dB reduction from the failure points are considered while the margin in WAIC studies was only 2 dB.
  - c.6 dB safety margin is considered that was not present in WAIC studies.
  - In total RTCA made the test inputs 16 dB more stringent for 5G than in their prior testing of WAIC.
- 3.The Worst-Case Landing Scenario (WCLS) used in AVSI's testing for the 200 ft height did not reflect realistic landing conditions. The 200 ft height was selected because the interference from the aircraft on the ground reached a maximum at 200 ft, an artificial construct. The interference from other radar altimeters in a real-world landing scenario would be 24 dB less.
- 4.Considering the same criteria is used for determining the interference tolerance thresholds for both blocking due to in-band transmissions and desensitization due to OOB interference from IMT systems, the difference between the thresholds would be the frequency offset selectivity/out-of-band rejection of the altimeters. Comparing the thresholds shows different frequency offset selectivity (out-of-band rejection) at different altitudes for the same category altimeters and they vary significantly. This is amplified by the fact that the thresholds in the RTCA report are based on the worst-case performance is provided but not for each altimeter type. Furthermore, there is no information on level of usage, i.e. market penetration of the different altimeter types. This is important as "pulsed" altimeters that were designed decades ago have much worse characteristics compared to the more modern altimeters using Frequency Modulated Continuous Wave (FMCW) technology. Hence, it is not possible to determine the extent of the altimeters with poor performing receiver selectivity.

Take-aways

- To resolve the potential interference and develop the regulatory framework to ensure the coexistence requires close cooperation on engineering level between mobile industry and aviation industry as early as possible.
- Non-standardized receiver performance of radio altimeter may prevent the countries from increasing spectrum usage efficiency. Since the flights could travel internationally, China aviation industry should replace those radio altimeters with bad blocking performance by regulatory method as early as possible.
- For the restricted deployment near the airports, mobile and aviation government regulators (agencies or ministries), mobile operators and aviation industry should collaborate to reduce the areas of the impacted zones.

To Be Continued

Qualcomm

Thank you

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