AVIATION WEEK NETWORK

OPERATIONS

5G A (Try Not To) Crash Course

To understand the current 5G versus radio altimeter frequency clash, understand what came before 5G.

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Like many professional pilots, I have been a beneficiary of faster cellular phones with broadband Internet service, giving me access to better aviation products that make my job easier. But also like many other pilots, I don't know what to make of the current 5G versus radio altimeter frequency clash.

A few months ago, a highly respected aviation expert assured us that there is nothing to worry about, radio altimeters are just advisory tools that we can simply ignore. I knew immediately that this is wrong, so his calming words only made we worry more. My path from then to now has been a series of questions with answers that start with a definitive yes, move to tentative maybes, and end with a simple, I don't know. And I don't like not knowing. If you fly an aircraft with a radio altimeter, this is stuff you should worry about.

Is the Fourth Generation (4G) Due to be Replaced? Yes.

With each new generation of cellular phone service, it is easy to marvel at the great leap over how things used to be, and it is hard to imagine how things could possibly get better. But looking back to the previous generation, we also wonder how it is we could have lived with such backward technology. To understand why 4G's days are limited, we need to look back to how it all started.

The first mobile phones were bulky affairs that amazed the world. A phone with no cord! The first generation of mobile networks—or 1G as they were retroactively dubbed when the next generation came along—was launched by Nippon Telegraph and Telephone (NTT) in Tokyo, Japan in 1979. The first 1G networks appeared in the U.S., Canada and the UK a few years later.

An early '1G' telephone before the term was coined.
Credit: Shutterstock

These phones used analog signals, meaning the sound was turned into either varying amplitudes or frequencies placed on top of a “carrier” signal. Every signal between a cellphone and a cellphone tower consumed a bit of the frequency. The frequencies assigned to cellphones quickly became congested. Coverage was poor and sound quality was low. Because the signal wasn’t encrypted, anyone with a radio scanner could eavesdrop on a call. Another issue with analog signals is that they tended to degrade with distance and were subject to losses when amplified.

The frequency bands were mostly in the 450-to-900 MHz range, which is fairly low. A low frequency has the advantage of being able to penetrate walls and to travel around objects, but it isn’t capable of carrying a lot of information. At its best, 1G was capable of transferring 2.4 thousands of bits per second, or 2.4 kbps. But still, no cord!

Second Generation

An example of a 2G cellular telephone.
Credit: Shutterstock

The second generation of mobile networks, 2G, was launched in 1991 as the Global System for Mobile (GSM) Communications. At first, GSM’s main innovation was to turn analog signals into digital, decreasing distortion, improving transmission distances, and allowing for more information to be transferred more quickly. It also introduced text messages. The second innovation was to use information packets.

Before packets, a call had to carve out a slice of the allotted frequency which became unavailable to others until you were done or otherwise disconnected. With the new technique, your call or other data is broken into smaller packets. Each packet includes a "decoder" known as a header. The header tells the system where the packet needs to go and tells the receiver how to combine all the packets back to their original state. Now your call could go to whatever parts of the frequency that were available. Early systems were known as the General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE).
2G expanded into previously unused frequencies, as high as 1,900 MHz. Higher frequencies could carry more data but had shorter ranges, necessitating more cell towers. By the end of the 2G era, speeds of 40,000 bits per second (40 kbps) and higher were achieved.

Third Generation
3G was launched in Japan in 2001 and included standardized network protocols, allowing data packets to be accessed worldwide. 3G data transfer was four times faster than 2G, allowing video conferencing, video streaming and voice over Internet. While most networks used the same frequency bands as 2G, some crept ever higher up to 2,100 MHz and were able to achieve speeds up to 42 millions of bits per second (42 Mbps).

An example of a 3G cellular telephone.
Credit: Shutterstock

An example of a 4G watch.
Credit: Shutterstock

Fourth Generation

4G was first deployed in 2009 as the Long Term Evolution (LTE) standard. Unlike the upgrade from 2G to 3G, which could be made by changing SIM cards, going to 4G required a new device. The payoff was speeds up to 1 gigabit per second (1Gbps). It is hard to imagine anything better, but as more people adopt the technology, the more crowded the frequencies become. In the UK, for example, residents are only able to access 4G about 53% of the time. New methods have been developed to cram more and more information into existing signals, but more areas of the world are running into bandwidth issues.

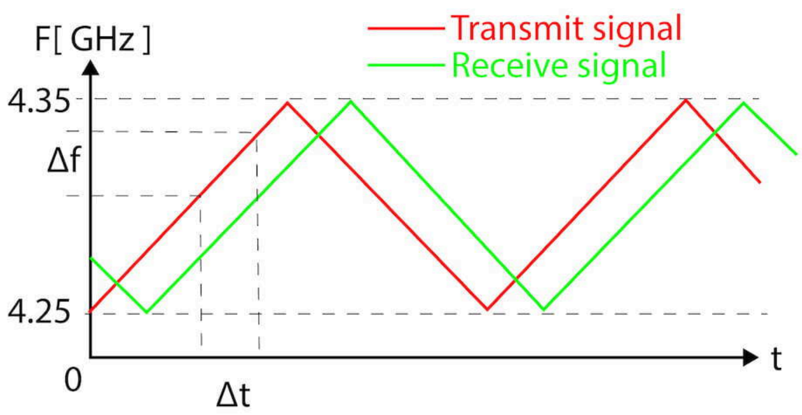
Is 5G Inevitable? Probably

From 1990 to 2015, the number of worldwide mobile subscriptions has exploded from around 12 million to nearly 8 billion. Even with the increased number of frequencies used by 4G systems and improved data handling, the worldwide appetite for bandwidth means we need more frequencies. We've exhausted the lower frequency bands, so the next direction is up.

Most of the existing mobile spectrum is between 300 MHz and 5 GHz. Lower frequency bands cover wider areas because they can penetrate objects effectively and thus travel further, including inside buildings. This means you can get by with fewer towers. But these bands tend to have lower capacity because the spectrum is in limited supply, so only narrow bands tend to be available. Coverage from higher frequencies is smaller because the signals can be weakened or stopped by obstacles, such as buildings. For this reason, higher frequencies require more towers. But higher frequencies allow broader frequency bands, allowing more data to be transferred. The result is the next generation, 5G, which carries more data and has speeds that can reach 1.8 Gbps.

Is 5G inevitable? Probably. We should never discount the possibility that the next best thing in technology is something nobody can imagine today. But for now, it seems 5G is coming. So, if 5G is inevitable, what is the problem? For most of the public, it is all those towers. Studies estimate that it will take 13 million utility-pole-mounted base stations in the U.S. to bring 1.0 Gbps to 55% of the population. The cost is estimated at $400 billion. For us in aviation, however, the problem could be worse than an unsightly cell tower or the price tag of the service.

Are Radio Altimeters At Risk? Possibly.



Credit: James Albright

You may have heard that the signal from a 5G tower or cellphone can interrupt the signal to and from your radio altimeter, with tragic impact. Maybe. Understanding the potential problem requires a deeper dive into radio altimeters, certification and the 5G frequency spectrum.

If you want to understand how your radio altimeter works, I recommend looking at Andreas Horn's article at www.engineeringpilot.com. He has graciously allowed me to paraphrase his work.

Most radar altimeters used in aviation employ the so-called Frequency-Modulated Continuous Wave (FMCW) principle. A carrier signal is modulated to produce a "sweep" over a given frequency range. This signal is transmitted via a transmission antenna to the ground. After propagation, the reflected signal is received via another dedicated receiver antenna. Part of the transmitted signal is coupled into the receiver path, where it is mixed with the received signal. This permits the determination of the frequency shift, which is representative for the propagation time and thus the distance traveled, which gives you the radio altitude.

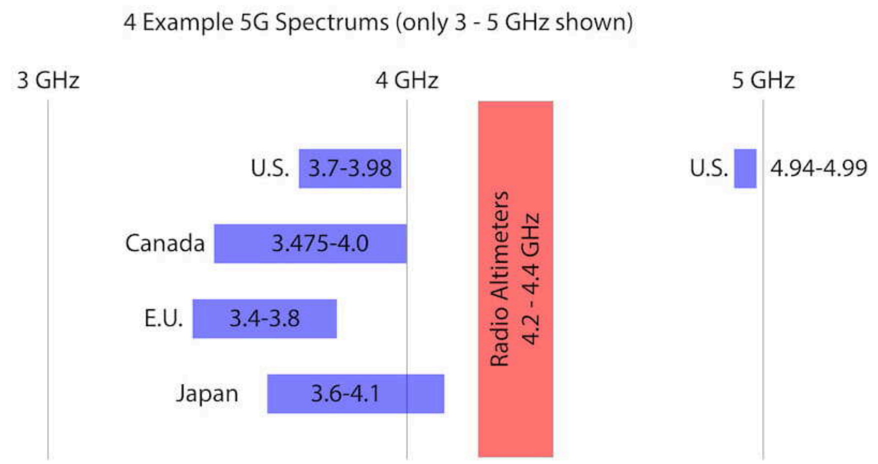
The electronics involved are often analog and thus quite sensitive to interference. Only few, more modern designs are based on digital technology which is more tolerant to disturbances. Most radio altimeters were designed under RTCA Minimum Operational Performance Standard (MOPS) DO-155, which in its legacy form does not mandate specific interference protection. High Intensity Radiation Field (HIRF) guidelines used for current airworthiness certification were calculated based on known transmission sources at the time, and 5G didn't exist then. In other words, the electric field strength levels in the current HIRF environments might not ensure sufficient protection against 5G interference.

Standards organization RTCA, originally known as the Radio Technical Commission for Aeronautics, established a task force to investigate the potential interference risk. The interference tolerance of typical radar altimeters was determined using bench testing. Then, a simulation was carried out to determine the typical interference levels "seen" by an operational aircraft in a 5G-environment. The report determined that significant interference must be expected, should the 5G communication systems be rolled-out without precautions.

5G Around The World

You may also have heard that the 5G problem for aviators is more acute in the U.S. than in other parts of the world. Radio altimeters operate at frequencies in the 4.2-4.4 GHz band. In most parts of the world, the lower-frequency 5G bands go no higher than 3.8 GHz, providing a 0.4 GHz (400 megahertz) buffer. But in the U.S., the band in question ends at 3.98 GHz, reducing our margin to 0.22 GHz (220 megahertz), about half. Some countries shave the margin even more thinly.

So, is your radio altimeter at risk to interference from 5G cellular systems? Possibly, but we don't have definitive proof of this. The RTCA says we should expect it.



Credit: Qualcomm

Is The FAA's Response Adequate? Probably Not.

In December 2021, the FAA issued Safety Alert for Operators (SAFO) 21007, Risk of Potential Adverse Effects on Radio Altimeters when Operating in the Presence of 5G C-Band Interference. The SAFO warns us: "Operators and pilots should be aware of aircraft systems that integrate the radio altimeter and should follow all Standard Operating Procedures related to aircraft safety system aural warnings/alerts."

On Jan. 13, 2022, the FAA issued 1,478 5G NOTAMS for airspace, aerodromes, instrument approach procedures and for special instrument approach procedures. Looking at an example aerodrome NOTAM can provide an idea of what to expect:

BDL AD AP RDO ALTIMETER UNREL. AUTOLAND, HUD TO TOUCHDOWN, ENHANCED FLT VISION SYSTEMS TO TOUCHDOWN NOT AUTHORIZED EXC FOR ACFT USING APPROVED ALTERNATIVE METHODS OF COMPLIANCE DUE TO 5G C-BAND INTERFERENCE PLUS SEE AIRWORTHINESS DIRECTIVE 2021-23-12

Are Reading and Following NOTAMs Enough? No.

Reading the example NOTAM could lead you to believe that if you are not using autoland, HUD-to-touchdown, or enhanced flight vision systems to touchdown, you have nothing to worry about. Looking at a list of possible affected systems given in the SAFO should dispel that notion:

- Class A Terrain Awareness Warning Systems (TAWS-A)
- Enhanced Ground Proximity Warning Systems (EGPWS)
- Traffic Alert and Collision Avoidance Systems (TCAS II)
- Take-off guidance systems
- Flight Control (control surface)
- Tail strike prevention systems
- Windshear detection systems
- Envelope Protection Systems
- Altitude safety call outs/alerts
- Autothrottle
- Thrust reversers
- Flight Director
- Primary Flight Display of height above ground
- Alert/warning or alert/warning inhibit
- Stick pusher / stick shaker
- Engine and wing anti-ice systems
- Automatic Flight Guidance and Control Systems (AFGCS)

Modern aircraft can be thought of as being more holistic than ever, just about everything is connected to just about everything else. You can no longer trace a schematic and definitely say that one particular system has no impact on others. For example, my aircraft, a Gulfstream GVII, filters Crew Alerting System (CAS) messages on a "need to know" basis. If we have an engine fire on takeoff, we don't get a warning until passing 400 ft. above the ground. Will 5G interference rob me of that information at a higher altitude? I don't know.

It could very well be that this is much ado about nothing. It could be that the 220 MHz buffer between 5G signals in the U.S. and our radio altimeters is more than ample. But I don't like trusting my fate to the word "could." The frequency auction in the U.S. earned the U.S. Federal Communications Commission over $81 billion in licensing fees. Can't a portion of that fully pay for a definitive study?

There are a lot of unknowns in this 5G mess and I hope it doesn't take something catastrophic in aviation to force a solution. The public's hunger for more bandwidth could be tempered by a realization that getting on an airplane is no longer as safe as they've come to appreciate. Or we may figure out a short-term solution to increase the frequency buffers and a long-term answer to redesign existing radio altimeters.

I think it is just as likely that the 5G price tag will inspire a 6G solution that makes all of this moot. As a professional pilot, my answer will be to watch everything like a hawk, suspect anything with a radio altimeter interface, and insist that crew and passengers place their cell phones in airplane mode when flying with me.

—***James Albright*** *is a retired U.S. Air Force pilot with time in the T-37B, T-38A, KC-135A, EC-135J (Boeing 707), E-4B (Boeing 747) and C-20A/B/C (Gulfstream III). Since turning civilian, he has flown the CL-604, Gulfstream GIV, GV, G450, and now the GVII-G500. He is the webmaster and principal author at* *Code7700.com*