Influence of New 5G Communication Interference on Flight Inspection

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ABSTRACT

The extension of new communication frequencies used for fifth generation (5G) cellular networks is currently causing intense discussions and additional operational constraints in the U.S. and Europe regarding the safety of landing aircraft, where the radio altimeter is the most important source. Commercial interests (of the cellular network providers) and safety constraints (of the airline industry) are clearly diametric in this case.

The international standardization documents for radar altimeters do not cover interferers in frequency bands adjacent to the radar altimeter's operating frequencies (4.2 to 4.4 GHz). Transmission of 5G signals in adjacent frequencies (which were assigned recently) could have a severe impact on the usability and reliability of the airborne radar altimeter. The radar altimeter system is a source for several aircraft systems, including safety critical functions, and is mandatory for low-visibility operations.

In order to address these issues, the involved partners tend to use individual approaches for analyzing and discussing the severity of possible radio frequency interference.

Equipment tests in the laboratory were performed to define the limits for of out-of-band signals. These are compared to the theoretical radiation power density and field strength of the 5G ground transmitters at each installation site. However, these tests are not completely representative for real-world operations.

This is why this paper will discuss the possible role of flight inspection for addressing these RFI issues. Well-equipped flight inspection aircraft have been monitoring radar altimeter readouts for inspecting ILS CAT II and III installations for years. In addition, flight inspection aircraft could be modified to measure possible interference from out-of-band signals close the radio altimeter operating frequency band during calibration flights or approaches. This way flight inspection could also supplement the validation of theoretical models.

In order to analyze the influence of 5G transmitters, the characteristics of the aircraft antennas, the aircraft's attitude as well as the positions of the aircraft and the transmitters need to be taken into consideration. This way, out-of-band interference signals can be measured with good reproducibility.

This paper will demonstrate how such a system could look like, what equipment would be required, and how the local (own) radar altimeter signals could be suppressed to enhance the sensitivity of the test system.

Based on such measurements, flight inspection can provide valuable input to the public discussion in order to maintain the highest level of safety in aviation.

INTRODUCTION

The extension of new communication frequencies used for fifth generation (5G) cellular networks is currently causing intense discussions and additional operational constraints in the U.S. and Europe regarding the safety of landing aircraft. Commercial interests (of the cellular network providers) and safety constraints (of the airline industry) are clearly diametric in this case.

The new cellular radio 5G stations are working close (in RF frequency) to the protected radio altimeter frequencies. Landing aircraft in low visibility conditions use the radio altimeter signal for the final phase of a CATII and III approach. Thrust reverser and automatic brake systems may also be connected to the radio altimeter signals.

The words/abbreviations of radio altimeter, radar altimeter and RadAlt have identical meaning and are used as equivalent in the following.

The following topics are discussed:

Situation before 5G
Situation with 5G
Technical description of RadAlt System and antennas
Signal strength estimations
Filter characteristics of antennas
Technical solution for Flight Inspection Systems
What is needed on board?
Example of 5G source on ground
What is the job of Flight Inspection in this matter

SITUATION BEFORE 5G

The first Radio Altimeter have been in service since the 1940´s (see **Figure 2**) In these days nearly no strong signals were present which could cause interference.

Current units were designed to meet TSO-C87 (Airborne Low-Range Radio Altimeter) [1]. It is based on a technical standard of early 1960s. Latest update was 1980 (see **Figure 1**. Tests for radio frequency susceptibility in those days were only specified up to 1000 MHz.

No specification of strong signals close to the operating frequency band of 4200 MHz to 4400 MHz and no specific requirements regarding interference susceptibility or receiver masks were published.

Department of Transportation¶
Federal Aviation Administration¶
Aircraft Certification Service¶
Washington, DC¶

TSO-C87¶

Date: 2/1/66¶

Technical·Standard·Order¶

Subject: TSO-C87, AIRBORNE LOW-RANGE RADIO ALTIMETER¶

Figure 1: TSO-C87 published 1966

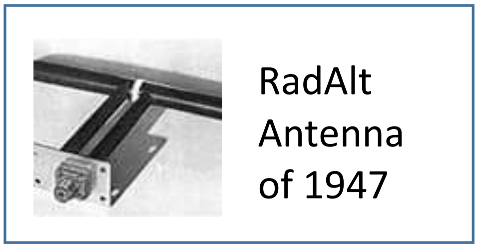


Figure 2: Sample of an early antenna (UHF?)

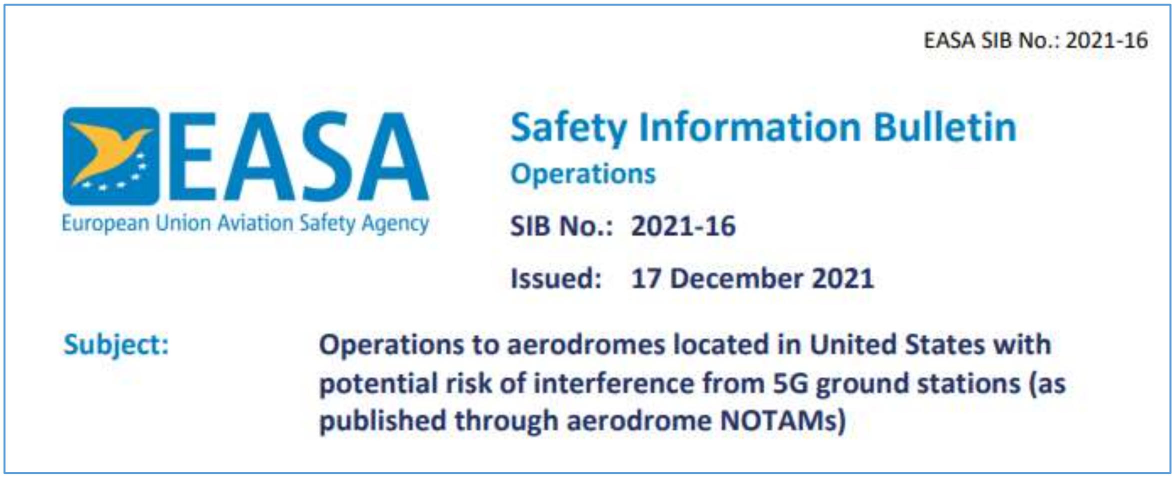
SITUATION AFTER 5G STATIONS INSTALLED NEAR AIRPORTS

Telecommunication providers have been deploying 5G ground stations (or 5G base stations) around the world. These 5G ground stations are operating in the C-band, at frequencies that are close to the frequencies utilized by the radio/radar altimeters installed on many aircraft.

This has led to concerns of potential interference of radio altimeters from 5G ground stations causing anomalous radio altimeter behavior.

The FAA and EASA issued several safety information to aircraft operators. (See Figure 3) Individual aircraft types and individual ground installations may be affected.

The situation in the U.S. is currently more severe than in Europe. This is caused by frequency assignment and location of the 5G stations installed, which is handled different in individual countries.



EASA SIB No.: 2021-16

EASA
European Union Aviation Safety Agency

Safety Information Bulletin
Operations
SIB No.: 2021-16
Issued: 17 December 2021

Subject: **Operations to aerodromes located in United States with potential risk of interference from 5G ground stations (as published through aerodrome NOTAMs)**

Figure 3: EASA Safety Bulletin December 2021

TECHNICAL DESCRIPTION OF RADALT SYSTEM NCLUSIONS

The RadAlt system works in the following way:

A transmitter on a center frequency of 4300 MHz is swept with a rate of about 50 Hz through a bandwidth of about 100 MHz. The emission type is 150MFXN, this is wideband frequency modulation with triangular modulation waveform.

The transmitter output power is 450 mW nominal. This signal is permanently transmitted through a designated RadAlt TX Antenna. An identical antenna is installed for the receiver.

Because of a time delay of the received signal (time to travel to the reflector and back) the (current)-TX and (delayed)-RX signal have different frequencies. This “delta f” is directly proportional to the height above the ground.

One example of a standard RadAlt system, taken from the technical data sheet[11]:

Sweeprate is 100 MHz in 20ms (50 Hz).
Height above ground is 1000 ft.
The speed of the electromagnetic wave is $3\ 10^8$ m/s. This equates to about 1 ft/ns.
Time to travel from aircraft to ground (1000 ft) and back (1000 ft) is therefore 2000 ns or 2 ms.
The difference frequency of the (current)-TX and (delayed)-RX signal is 2ms/20 ms * 100 MHz = 10 MHz.
This is converted by calibration of the indicator to show 1000 ft.

Typical Antennas:

Two types of antennas are often used.

	
Typical flat antenna	Typical horn antenna

Figure 4: typical antennas

The flat antenna is a printed PCB board with linear signal polarization (direction of the arrow). It may have limited bandwidth.

The horn antenna is a classical broadband horn with linear polarization. Typical gain within one octave is constant. See Figure 8 for gain versus frequency plots.

RX and TX antennas must be orientated in the same polarization. Arrows must show in the same direction. It will not work if one antenna is turned 90°.

MEASUREMENT OF OWN SIGNAL

The own RadAlt TX signal was measured below the aircraft on ground as reference with the existing RadAlt transmitter and a standard RadAlt RX antenna. The RX antenna was placed about 20 cm below the transmitter antenna.

Figure 5: Set up of test below aircraft on ground.

A spectrum analyzer was used to display the received signal.

Spectrum GPS 05/04/22 15:51

Ref: 10.0 dBm RBW: 3 MHz SWT: 20 ms Trace: Max Hold

Att: 30 dB VBW: 3 MHz Trig: Free Run Detect: Max Peak

Center: 4.300000026 GHz Span: 500 MHz

Collecting data

Final plot(MAX HOLD)

Figure 6: Spectrum plots

Because the bandwidth of the analyzer was not covering the full 100 MHz band, several sweeps and the MAX HOLD function has to be used to show the occupied bandwidth. An analyzer with full 100 MHz bandwidth would catch the transmit signal within one sweep.

SIGNAL STRENGTH ESTIMATION OF OWN RAD ALT

A rough calculation of typical RadAlt signal as transmitted from the aircraft and received back was performed.

TX output power of 0.45 W	+26.5	dBm
TX antenna gain typ. :	+9	dBi
Free airspace attenuation for 1000 ft	-94.6	dB
Signal on ground RX with 0dBi antenna -59.1 dBi		
Perfect reflector 100% (metal, big, flat)	0	dB
Additional attenuation way back	-6	dB
RX antenna gain typ. :	+9	dBi
	__________	
RX signal at antenna	-56,1	dBm

The reflection coefficient of the ground is unknown, could be e.g. -30 dB, then a typical RX signal is about

-86,1 dBm

This is a typical value in practice.

Note: This is a rough calculation only as an overview. Reflection from ground is dependent from surface material, humidity, plants and several other parameter.

SIGNAL STRENGTH ESTIMATION OF EXTERNAL 5G

A typical situation of a new 5G station installed on an airport in the approach area is taken as an example. A transmitter power of 500 W for one frequency band is estimated.

In this example the aircraft is passing a main beam of a ground station in a distance of 1000 ft, as typical in approach, if the 5G station is next to or on the airport.

TX output power of 500 W	+57	dBm
TX antenna gain typ. :	+9	dBi
Free airspace attenuation for 1000 ft	-94.6	dB
RX antenna gain typ. :	+9	dBi
RX signal at antenna	-19,6	dBm

This is the power on the operating frequency of the 5G station, not the RadAlt frequency, but not far off.

There it will be about 65 dB stronger than the own RadAlt RX signal.

To forecast any influence on the operation of the radio altimeter, it must be known, what kind of overload-protection the RadAlt RX for strong out-of band signals has installed.

These values are not published and only known to equipment manufacturer and system integrators. So any combination of RadAlt TX/RX, type of antennas, location of antennas and aircraft fuselage may have different overload-limits.

IS THE RAD RX ANTENNA A GOOD FILTER?

The aircraft RadAlt RX antenna can help as a pre-filter by angular gain reduction (sidewards) or by frequency depending reduction of the signal.

Both elements are not effective to keep strong 5G out-of-band signals away from the receiver.

Measurements in the laboratory have been performed to get the basic antenna characteristics. Relative antenna gain was measured in forward and sideward direction of the antenna. See Figure 7 for results. The blue line shows the antenna gain in FWD/AFT direction and the red line in LEFT/RIGHT direction.

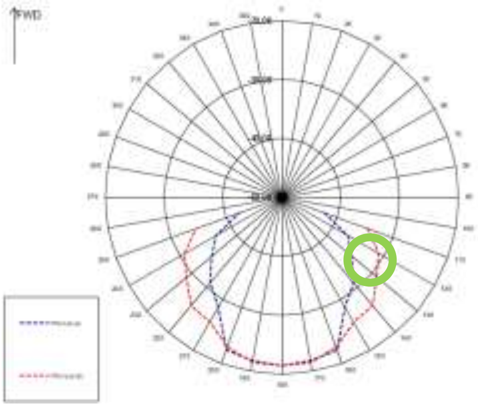


Figure 7 Angular antenna gain variation

As an example, a 30° angle from the horizontal line was taken. The gain reduction compared to the vertical is resulting in about 10 dB signal reduction in 30 ° downward direction from aircraft when passing abeam the 5G station.

The gain versus frequency measurement was performed with a broadband TX antenna and one of the typical RX antenna. Coupling was measured with a network analyzer.

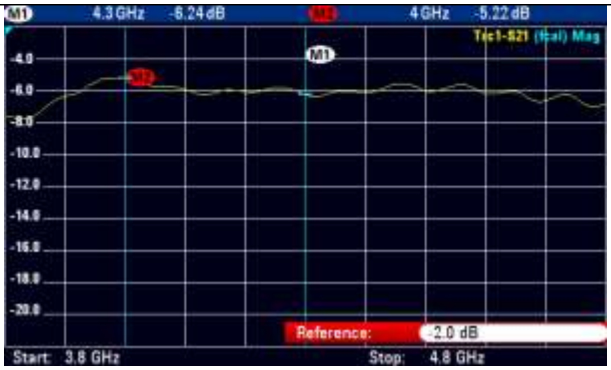
	
Frequency response of a FLAT antenna	Frequency response of a HORN antenna

Figure 8: Gain versus frequency plots

The frequency versus gain plot shows, except one dip at 4 GHz at the FLAT antenna, no relevant signal reduction within 500 MHz bandwidth, centered at 4300 MHz.

This comes to the result, that typical Rad Alt RX antennas are NO good filter for 5G out-of RadAlt-band signals.

TECHNICAL SOLUTION FOR FLIGHT INSPECTION SYSTEMS

A full equipped flight inspection system already has the main components for recording 5G signals available.

Out of band signals can be measured and recorded on board of this flight inspection aircraft. The signal of an additional, new antenna must be connected to a spectrum analyzer. Installation must be capable to work in the 4.3 GHz band.

An example of possible signals are given in the following (see Figure 9) without and with 5G station around. Signal levels are not to scale and may differ in real situations.

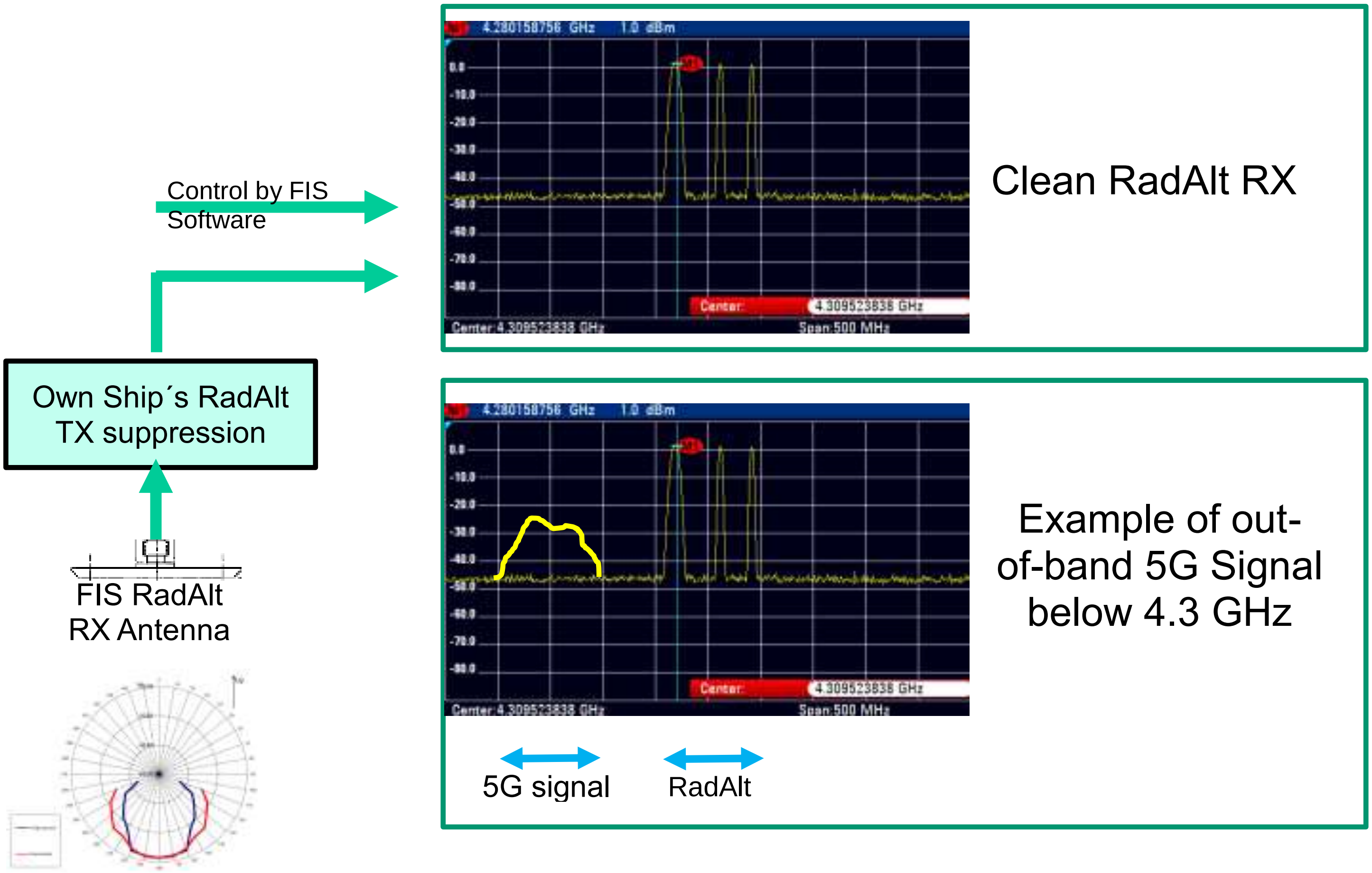


Figure 9: Signal flow of airborne system

WHAT IS NEEDED ON BOARD?

If the FIS aircraft shall detect and record 5G signals, it needs:

- A good spectrum analyzer capable up to 5 GHz
- An additional RadAlt RX antenna
- Some equipment to reduce the own RadAlt TX signal on the SPA RX antenna
- Software control of the RadAlt 5G test procedures

To save time and get a full overview in one sweep, it is recommended to have

- High Spectrum analyzer bandwidth for quick measurements

For quick detection of a 5G provider, it nice to have

- Database with known 5G stations including assigned frequencies

EXAMPLE OF A REAL SIGNAL AND IDENTIFICATION OF THE SERVICE PROVIDER

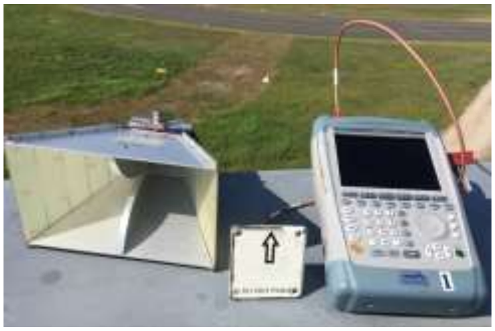
A 5G Signal of an existing 5G ground station was received, who is the source?

As an example a measurement on ground was performed, 300 m abeam of the threshold RWY 08 in Braunschweig Airport Germany, EDVE, on top of a building (10 m AGL). The equipment is shown in Figure 10

In knowledge of the frequency assigned to each 5G service provider (public available), these signals could be referenced to a single service provider and depending on the number of stations of this provider in the near surrounding area, it may be possible to assign this signal to a single transmitter tower.

The identification was done manually in the test, but together with a 5G database it could be automated.

With the simple test set up of a spectrum analyzer and a RX antenna the maximum level was detected in the horizontal direction and in this position a MAX HOLD measurement was taken. By simply comparing the plot with the published data the station could be identified (see Figure 11).



Horn and flat A/C antenna had nearly identical signals

Figure 10: Detection of 5G signals on ground

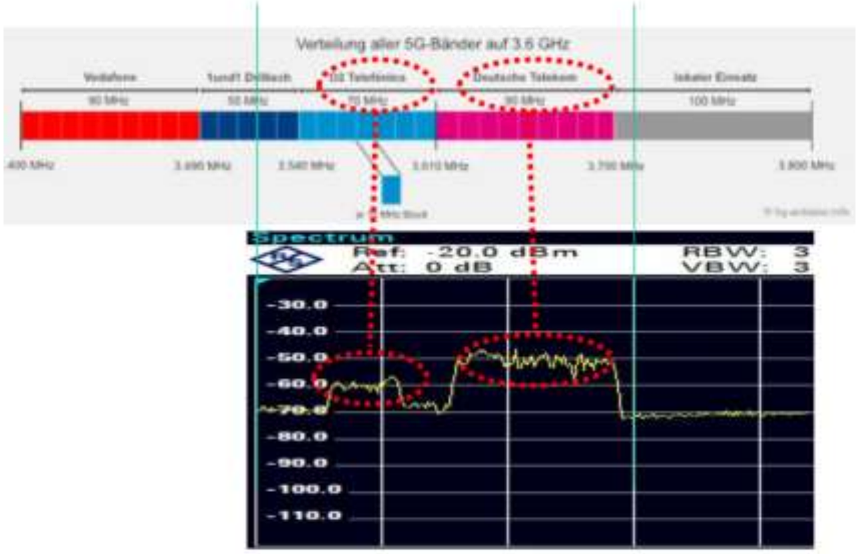


Figure 11: Identifying service provider by public available frequency charts

WHAT IS THE JOB OF FLIGHT INSPECTION IN THIS MATTER

A full equipped (ILS CAT III) Flight Inspection Aircraft has already a connection to the on-board RadAlt system and validates the RadAlt readouts with an independent height-sensor. This shows the indicated surface height and must match the indication of the barometric altimeter within the limits of the CAT III regulations. Any unstable signals with this aircraft installation could be easily identified (see Figure 12)

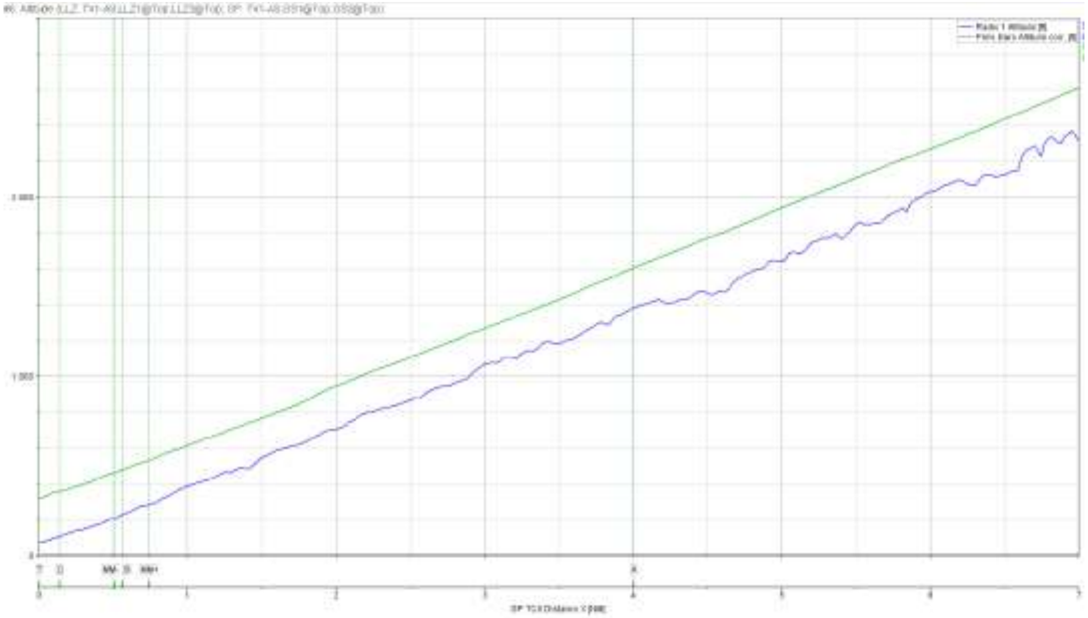


Figure 12 Typical Radar Altimeter Plot at a CAT III approach

The green line shows the altitude reference line and the blue line shows the actual RadAlt output. The reference is primary barometric altimeter, corrected to QNH. The difference shows the altitude of the airport above MSL and is no failure. No indications of disturbed or unstable signals are visible. It must be taken to notice, that a clean signal at this location only represents one dedicated type of RadAlt system. Other manufacturer or other installations on aircraft may be more sensitive to 5G signals.

With this plot showing no problems, in parallel the spectrum analyzer can be used to record out-of-band power levels.

For the 5G interference judgement, the following action has to be made:

- The flight inspection system is taking measurements and recordings of the local interference situation including a few 100 MHz next to the assigned RadAlt band.

- The FIS can only make the decision, if the installation is conform or not conform with current regulations, if the limits are published.

In the current situation, technical and operational limits must still be defined by regulators (local) or similar organizations (ICAO?) and be implemented in the FIS. Without these manufacturer data a good/no good statement cannot be performed by the flight inspector.

CONCLUSION

The flight inspection system can be used to measure and record the current 5G spectrum. It can also monitor the stability of the RadAlt signal with the own aircraft´s radio altimeter system.

Limits for out-of-band signals close to the protected 4.2 to 4.4 GHz band must be published by the authorities or other accepted institutions.

In the future a technical solution must be developed by the radio altimeter manufacturer or system integrators, to suppress (filter out) strong unwanted signals.

The safety analysis of aircraft must be enhanced to point out the risk of wrong RadAlt indications and the safety effect arising thereof. In the meantime frequency assignment to new 5G stations must be observed to avoid critical situations.

REFERENCES

[1] Technical Standard Order TSO-C87a

[2] ITU Radio Regulations, Articles, Edition of 2020, article 5: Frequency allocations for the whole world (Region1, 2 and 3)

[3] RTCA DO-155

[4] EUROCAE ED-30

[5] Rockwell Collins Alt 4000 technical specification

[6] EASA and FAA Safety Information Bulletins