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# RTCA Special Committee 186, Working Group 5

# ADS-B UAT MOPS

# Meeting #10

# Draft 3 of the consolidated UAT Standard Interference Environment

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| SUMMARY |
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## G.1 Background

The UAT is designed to operate in the lower portion of the 960-1215 MHz aeronautical radionavigation service (ARNS) band. This portion of the band is heavily utilized throughout the world for International Civil Aviation Organization (ICAO) standard systems such as distance measuring equipment (DME), and military systems such as Tactical Air Navigation (TACAN), and in some States Joint Tactical Information Distribution System/Multifunctional Information Distribution Systems (JTIDS/MIDS). Each of these systems share a common characteristic in that they utilize pulses that are short in relation to UAT pulses. As a result, the UAT waveform and receiver front-end has been specifically tailored to tolerate a high-density pulsed environment. In addition, the random-start nature of the UAT ADS-B access protocol results in self-interference. The extent of this interference is dependent on the number of aircraft visible to the "victim" UAT.

Due to the complexity of the potential interference environment, UAT performance in an operational environment was determined through the use of high-fidelity computer simulations. Those simulations were based on two specific inputs:

1. the performance of the UAT receiver in the presence of interference[1] as a function of signal-to-interference and desired-to-undesired signal overlap; and

2. the time/amplitude distribution of interfering signals.

This appendix will address the assumptions driving the latter input, while the UAT test specifications (Section 2.4) will ensure that UAT equipment complying with this MOPS can match the assumed UAT performance.

## G.2 Operational Environments

The UAT 978 MHz operating frequency was selected to minimize the impact to existing DME/TACAN use. That DME/TACAN channel (17X) is reserved worldwide for "emergency use", and as a result there are very few operational 978 MHz DME/TACAN systems. In the United States for example, both 978 MHz and 979 MHz are reserved for DME "ramp tester" equipment. Such an application is very low power, offering no interference to UAT use[2]. Europe however does use both 978 MHz and 979 MHz for operational DME/TACAN, so European scenarios considered DME/TACAN as an interference source. It should be noted that early test and analysis results indicated that, for off-board DME/TACAN, only those that were co-frequency and/or adjacent-frequency to the UAT (i.e., on 978 or 979 MHz) need be considered. This accrued as a result of the narrow spectral content of the DME/TACAN signals, in concert with the good frequency rejection properties of the UAT receiver.

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[1] This performance was quantified through high-fidelity bench test measurements.
[2] Testing and analysis has also shown that co-frequency UAT usage will not interfere with ramp tester implementation.

Driven by the diverse environments in which UAT would operate, a number of different interference scenarios were postulated and simulated. The goal was to ensure that the UAT design would provide the necessary performance as UAT traffic increases in the future and to ensure that UAT receivers are measured against the most challenging interference environment from JTIDS/MIDS[3] and DME sources. Within a given scenario, UAT receiver locations were chosen to represent the most challenging geographic areas.

To analyze DME interference in core Europe, the International Civil Aviation Organization (ICAO) database of existing and planned DME/TACAN assignments was examined. While the underlying assumption for DME/TACAN is that co-channel assignments will eventually need to be moved in order to achieve full operational UAT performance, it is also recognized that in the near-term low-density UAT environments could accommodate co-channel DME/TACAN interference. As a result, the UAT design has been tailored to ensure that UAT can provide an adequate level of performance as 978 MHz DME/TACANs are reassigned over time. Furthermore, since current "planned" assignments allow latitude for regulators to expand usage of 979 MHz, assumptions were made to predict future DME/TACAN interference. In particular, for the Core Europe 2015 scenario, it was assumed that while all 978 MHz DME/TACANs were reassigned, all planned 979 MHz assignments in ICAO data base had become operational. In total, the goal of each of the test scenarios was to reasonably over-bound any operational environment the UAT could be expected to experience.

Aircraft distributions were based on scenarios developed by the joint Federal Aviation Administration (FAA)/Eurocontrol Technical Link Assessment Team (TLAT) to assess candidate ADS-B links. One scenario was intended to represent a low-density air traffic environment, while another mimicked introducing UAT into today's Core Europe setting. The final two "future" scenarios predicted Los Angeles Basin 2020 and Core Europe 2015 environments respectively. Together these scenarios provided diverse assessments of UAT performance, and their characteristics are catalogued in Table G-1. Note that to fully assess the resulting performance of a victim UAT receiver, practical UAT receiver implementation limitations that impact receiver availability are also included.

## G.3 Cosite Environment

In addition to all the scenarios for the external interference environment, effects were included to account for on-board sources of interference from co-aircraft L-Band systems. The components of this co-site environment were estimated during the TLAT deliberations and have been further refined for the expected UAT aircraft installations. This environment was selected to be conservative and consistent for all aircraft classes, which resulted in including, for example, the assumption that A0 aircraft could be equipped with airborne collision avoidance systems (ACAS). The cosite environment is defined in Table G-2, depicting the assumptions of transmission duration and rates of onboard L-Band transmitters, including signals from onboard

[3] JTIDS/MIDS scenarios are defined in terms of source time slot duty factor (a measure of number of pulses per second), and source received power level. For the MOPS effort a number of operational JTIDS/MIDS scenarios were provided by the US Department of Defense as representing postulated training needs. These were included as part of the standard interference environment as shown in Table G-1.

DME equipment, TCAS and transponders. Also noted is the allowance made for receiver recovery time under the assumption that pulse suppression circuitry is employed.

## G.4 Scenario Assessments

With the preceding environments established, ADS-B reception performance was assessed for various receiver types in various locations within the environment[4]. The primary metric was the update interval achieved at a 95% confidence level for 95% of the aircraft population of interest. In assessing air-air surveillance performance, the aircraft population of interest was limited in elevation relative to the own aircraft in order to eliminate targets that were of no operational interest (see Figure G-1).

Table G-3 is a matrix delineating the individual simulations performed in making design decisions for this MOPS. Results from a select subset of these simulation runs are provided in Appendix ***TBD*** to indicate performance that can be expected of a UAT built to the standards of this MOPS.

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[4] It is recognized that UAT ground stations in close geographic proximity to 978 or 979 MHz DME/TACAN transponders may require special siting to ensure proper operation of the UAT equipment.

## Table G-1: Interference Scenarios and Implementation Assumptions

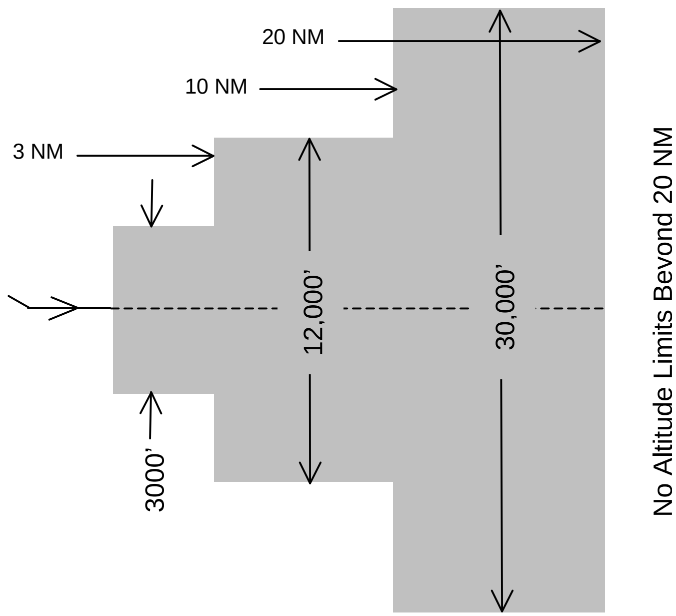
| | | Scenarios | | | |
|---|---|---|---|---|---|
| | | **Core Europe 2015** | **Core Europe Current** | **LA 2020** | **Low Density** |
| Standard Interference Environment | UAT Self Interference | Per TLAT Core Europe 2015 (2091 a/c in 300 NM radius) + 100 Surface vehicles per major airport @ 28-32 dBm and 1 Basic msg/sec | 1193 aircraft 500 ground vehicles 300 NM radius | Per TLAT LA 2020 (2694 a/c in 400 NM radius) + 100 Surface vehicles per major airport @ 28-32 dBm and 1 Basic msg/sec | Per TLAT Low Density (360 a/c in 400 NM radius) + No surface vehicles |
| | DME | All currently planned 979 assignments (Al Muaddi to translate into the signal conditions present for each victim situation; # and pwr) | All current 978 and 979 assignments 978: # and pwr 979: # and pwr | None | Same DME environment as CE 2015 |
| | JTIDS (levels seen at UAT victim antenna port) | TSDF 50% @ -39 dBm + TSDF 50% @ -60 dBm + TSDF 300% @ -84.5 dBm | TSDF 50% @ -39 dBm + TSDF 50% @ -60 dBm + TSDF 300% @ -84.5 dBm | TSDF 50% @ -39 dBm + TSDF 50% @ -60 dBm + TSDF 300% @ -84.5 dBm | TSDF 50% @ -39 dBm + TSDF 50% @ -60 dBm + TSDF 150% @ -78 dBm + TSDF 150% @ -82 dBm |
| Installation and Implementation Assumptions | Co-site | See "Co-site Events" table (scenario independent) | | | |
| | UAT Implementation Effects (Applies to all classes) | Re-trigger capable | | | |
| | | T/R switching results in 2 millisecond receiver blanking immediately before and after own-ship transmissions | | | |
| | | -20 dBc pedestal for 4 usec duration immediately before and after own-ship transmission | | | |
| | | "Pulse stretching" effects from high level DME seen in bench tests of "Pre-MOPS" units included in model | | | |

**Table G-2:** **Cosite Environment**

| Event | Event Blanking Interval (usec) | | Events per Second | | | |
|---|---|---|---|---|---|---|
| | Event Duration | Additional Blanking due to Rx Recovery | **A0** | **A1** | **A2** | **A3** |
| DME Interrogations | 19 | ??* | 70 | 70 | 70 | 70 |
| ATCRBS Replies | 20 | ??* | 200 | 200 | 200 | 200 |
| Mode S Replies | 64 | ??* | 4.5 | 4.5 | 4.5 | 4.5 |
| Mode S Interrogations | 20 | ??* | 5 | 5 | 5 | 5 |
| Whisper Shout Interrogations | 25 | ??* | 80 | 80 | 80 | 80 |

*No allowance for this currently. FAA-TC tests will determine if necessary. Can be capped at 15 usec by assuming supression circuitry is in effect.

**Figure G-1:** **Targets of Interest for Computing Update Interval**



## Table G-3: Overview of Scenario Assessments

| Perspective of Victim Receiver | | | Scenario | | | |
|---|---|---|---|---|---|---|
| **Location** | **Altitude** | **Rx Type** | **Core Europe 2015** | **Core Europe Current** | **LA 2020** | **Low Density** |
| At Scenario Center | 40,000’ | A2/A3 | x | | x | x |
| | | A1 | x | | x | x |
| | | A0 | | | | |
| | 15,000’ | A2/A3 | x | | x | |
| | | A1 | x | | x | |
| | | A0 | x | | x | |
| | On Approach (2000’) | A0[5] | x | | x | x |
| | On Surface (979 Mhz DME @ -10 dBm) | A0[6] | x | | x[7] | x |
| | | Ground Station | x | | x[8] | x |
| | | Ground Station[9] | x | | | x |
| At DME “Hot Spot” | 40,000’ | A2/A3 | x | | | |
| | | A1 | x | | | |
| | | A0 | | | | |
| | 15,000 | A2/A3 | x | | | |
| | | A1 | x | | | |
| | | A0 | x | | | |

[5] Update intervals based on B2 vehicle “probe” on surface approaching from 20 miles
[6] Update intervals based on A0 aircraft “probe” approaching from 20 miles at 2000’
[7] No DME interference included in this case
[8] No DME interference included in this case
[9] With cavity filter in line that is assumed to reduce DME interference to that equivalent of on-channel DME at –50 dBm. Filter assumed to introduce insertion loss of 4 dB