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RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #11

Draft 4 of Appendix G for Review in Brussels

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SUMMARY
This is Draft 4 of the Appendix G: Standard Interference Environment, even though it is the first actual draft identified specifically as Appendix G. This document was reviewed in the Atlanta meeting and approved for Plenary review with changes suggested there, and implemented in this revision.

Appendix G

Standard Interference Environment

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G.1 Background

The Universal Access Transceiver (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 countries the 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.

Because of 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 meeting this MOPS can match the assumed UAT performance.

G.2 Operational Environments

The operating frequency of UAT at 978 MHz 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 exist 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 first 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.

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

[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.

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.

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.

To analyze DME interference in core Europe, the International Civil Aviation Organization (ICAO) database[4] 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 self-interference environments offer performance margin that could be used to accommodate co-channel DME/TACAN interference. Geographic analysis of existing DME/TACAN assignments – i.e., quantifying the number and power of received DME/TACAN signals at geographic points in space – resulted in development of the environments shown in Table G-2 to capture current worst-case DME/TACAN conditions. In recognition of future environments, the UAT design was tailored to ensure that UAT could provide an adequate level of performance as 978 MHz DME/TACANs are reassigned over time. As part of this, noting that 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 database had become operational. Details of the resultant environments are captured in Table G-3. 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.

Sample Derivation:

Figure G-1 illustrates a scenario in today's environment focusing on an aircraft at 40,000 feet flying over Germany. Using the DME/TACAN emitter location and power information from the ICAO database, the DME and TACAN normalized ground station antenna patterns shown in Figures G-2 and G-3, relative emitter-aircraft geometry, and propagation loss equations, the values in Table G-4[5] can be derived. Repeating for various locations/geometries allowed the worst-case positions to be determined and utilized for compatibility analyses.

[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.
[4] Listings were reviewed/verified by Eurocontrol.
[5] Note these levels are also reflected in row 4 of Table G-2. The "All Germany" emitter reflects a mobile TACAN. For the purpose of this assessment it was placed in the worst-case location allowed by channel assignment rules.

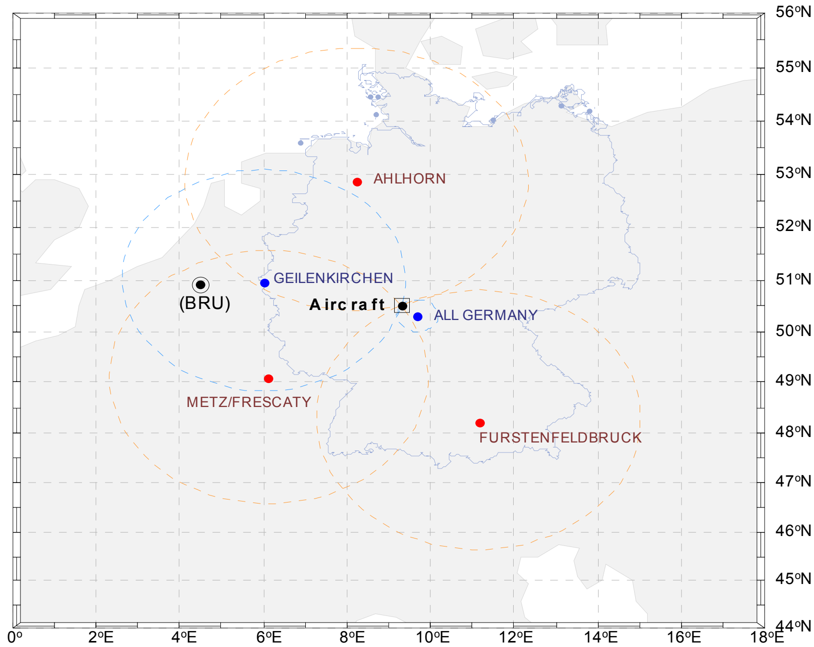

Figure G-1: **Sample Scenario**

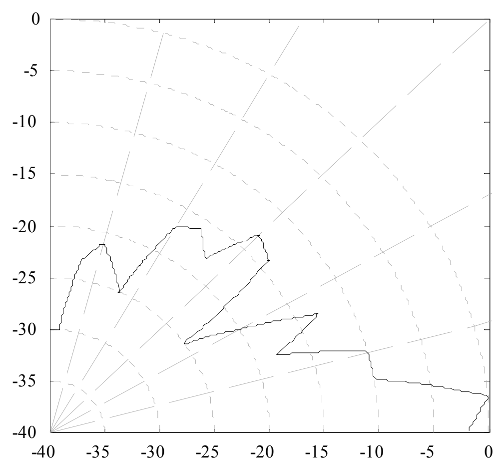

Figure G-2: **Normalized DME Pattern**

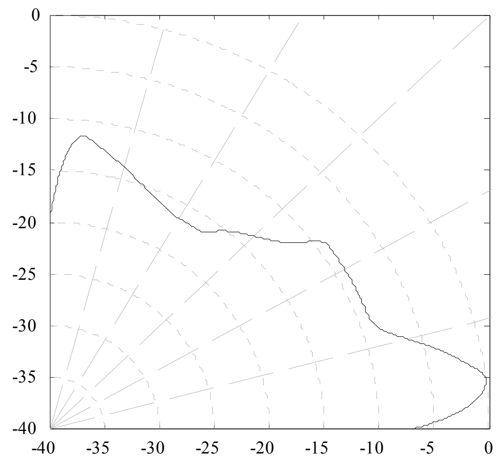

Figure G-3: Normalized TACAN Pattern

Table G-4: Signal Level Analysis of Sample Scenario

	AHLHORN	FURSTENF…	METZ/FRE…	GEILENKI…	ALL_GERM…
Type	TAC	TAC	TAC	TAC	Mobile TAC
Longitude (deg)	8.233	11.150	6.133	6.017	9.298
Latitude (deg)	52.883	48.217	49.067	50.967	50.525
Frequency (MHz)	978	978	978	979	979
Ground Distance (nmi)	148.7	155.2	150.1	128.0	1.5
Elevation Angle (deg)	2.54	2.43	2.51	2.94	77.13
EIRP (dBm)	70	70	70	67	70
Normalized Ground Antenna Gain (dB)	-2.67	-2.81	-2.71	-2.19	-13.25
Free-Space Propagation Loss (dB)	-141.05	-141.42	-141.14	-139.77	-114.19
Rec. Power at Aircraft Antenna (dBm)	-73.72	-74.23	-73.85	-74.96	-57.44

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 cosite 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-5, depicting the assumptions of transmission duration and rates of onboard L-Band transmitters, including signals from onboard 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[6]. 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 from consideration targets that were of no operational interest (see Figure G-4).

Table G-6 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 K to indicate performance that can be expected of a UAT built to the standards of this MOPS.

[6] 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

<table>
<tr><th colspan="2"></th><th colspan="4">Scenarios</th></tr>
<tr><th colspan="2"></th><th>Core Europe 2015</th><th>Core Europe Current</th><th>LA 2020</th><th>Low Density</th></tr>
<tr><td rowspan="3">Standard Interference Environment</td><td>UAT Self Interference</td><td>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</td><td>1193 aircraft
500 ground vehicles
300 NM radius</td><td>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</td><td>Per TLAT Low Density
(360 a/c in 400 NM radius)
+
No surface vehicles</td></tr>
<tr><td>DME</td><td>All currently planned 979 assignments
See Table G-3</td><td>All current 978 and 979 assignments
See Table G-2</td><td>None</td><td>Same DME environment as CE 2015</td></tr>
<tr><td>JTIDS
(levels seen at UAT victim antenna port)</td><td>TSDF 50% @ -39 dBm
+
TSDF 50% @ -60 dBm
+
TSDF 300% @ -84.5 dBm</td><td>TSDF 50% @ -39 dBm
+
TSDF 50% @ -60 dBm
+
TSDF 300% @ -84.5 dBm</td><td>TSDF 50% @ -39 dBm
+
TSDF 50% @ -60 dBm
+
TSDF 300% @ -84.5 dBm</td><td>TSDF 50% @ -39 dBm
+
TSDF 50% @ -60 dBm
+
TSDF 150% @ -78 dBm
+
TSDF 150% @ -82 dBm</td></tr>
<tr><td rowspan="5">Installation and Implementation Assumptions</td><td>Co-site</td><td colspan="4">See Table G-5
(scenario independent)</td></tr>
<tr><td rowspan="4">UAT Implementation Effects
(Applies to all classes)</td><td colspan="4">Re-trigger capable</td></tr>
<tr><td colspan="4">T/R switching results in 2 millisecond receiver blanking immediately before and after own-ship transmissions</td></tr>
<tr><td colspan="4">-20 dBc pedestal for 4 usec duration immediately before and after own-ship transmission</td></tr>
<tr><td colspan="4">“Pulse stretching” effects from high level DME seen in bench tests of “Pre-MOPS” units included in model</td></tr>
</table>

Table G-2: Received Power Levels (dBm) for Current European DME/TACAN Environment

Aircraft (Lat, Lon)	Alt (ft)	AHLHORN	METZ/FRE…	FURSTENF…	ALL_GERM…	BRUGGEN	GEILENKI…
50.9 deg, 4.5 deg	40000	-76	-72		-79	Not Operational	-66
50.9 deg, 4.5 deg	15000		-75				-69
50.5 deg, 9.3 deg	40000	-74	-74	-74	-57		-75
50.5 deg, 9.3 deg	15000	-76	-76	-77	-53		-78

Table G-3: Received Power Levels (dBm) for 2015 European DME/TACAN Environment

Aircraft (Lat, Lon)	Alt (ft)	AHLHORN	METZ/FRE…	FURSTENF…	ALL_GERM…	BRUGGEN	GEILENKI…
50.9 deg, 4.5 deg	40000	Assumed Cleared			-77	-76	-66
50.9 deg, 4.5 deg	15000				-68	-76	-69
51.0 deg, 6.0 deg	40000				-70	-76	-62
51.0 deg, 6.0 deg	15000				-72	-72	-56

Table G-5: Cosite Environment

Event	Event Blanking Interval (usec)		Events per Second			
	Event Duration	Additional Blanking due to Rx Recovery	**A0**	**A1 (L)/(H)**	**A2**	**A3**
DME Interrogations	19	15 usec	70	70	70	70
ATCRBS Replies	20	15 usec	200	200	200	200
Mode S Replies	64	15 usec	4.5	4.5	4.5	4.5
Mode S Interrogations	20	15 usec	5	5	5	5
Whisper Shout Interrogations	25	15 usec	80	80	80	80

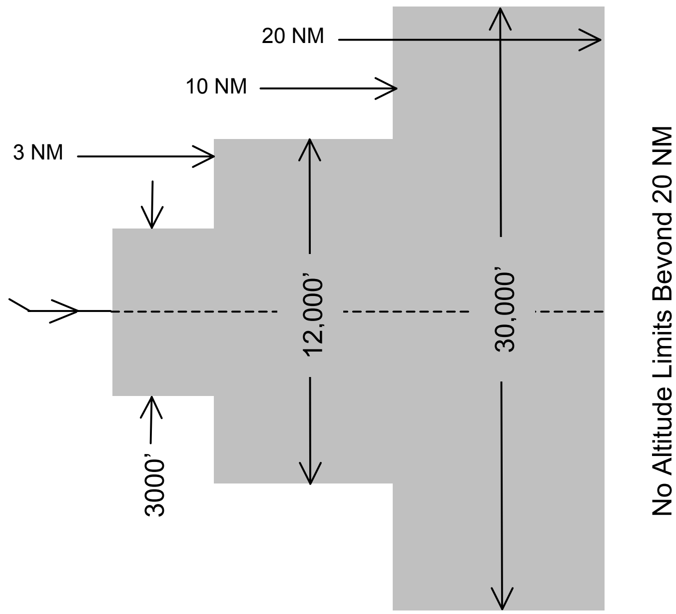

Figure G-4: Targets of Interest for Computing Update Interval

Table G-6: 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’	A3	**x**	**x**	**x**	**x**
		A2	**x**	**x**	**x**	
		A1	**x (H)**	**x(H)**	**x (H)**	
	15,000’	A2/A3	**x**	**x**	**x**	
		A1	**x**	**x**	**x**	
		A0	**x**	**x**	**x**	
	On Approach (2000’)	A0-A3[7]	**x**	**x**	**x**	
	On Surface (979 MHz DME @ -10 dBm)	A0[8]	**x**		**x**[9]	
		Ground Station	**x**		**x**[10]	
		Ground Station[11]	**x**			
At Worst Case DME	40,000’	A3	**x**	**x**		**x**
		A2	**x**	**x**		
		A1	**x(H)**	**x(H)**		
	15,000	A2/A3	**x**	**x**		
		A1	**x**	**x**		
		A0	**x**	**x**		

[7] Update intervals based on aircraft “probe” approaching from 20 miles
[8] Update intervals based on aircraft “probe” approaching from 20 miles at 2000’
[9] No DME interference included in this case
[10] No DME interference included in this case
[11] 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