RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #3

Example Link Budgets

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SUMMARY
This document presents several sample link budgets, for use in discussions of the equipment classes defined in Section 2.1 of the UAT MOPS.

Introduction:

This paper presents several examples of link budgets for the UAT. This paper serves to illustrate some of the factors that lead to the equipment class requirements in the draft of Section 2.1 of the UAT MOPS.

Assumptions:

This paper assumes the receiver noise bandwidth is similar to existing Capstone-style equipment, with a noise bandwidth of 1.5 MHz (-3 dB), and operating at 981 MHz. Further improvements in receiver sensitivity by using narrower bandwidth are ongoing, and may be the subject of further reports. This may lead to further revisions to MOPS Section 2.1 prior to the final draft.

Antennas:

The typical antenna for UAT link modeling has been an omnidirectional device with uniform gain of 0 dB. This antenna is used in most of the cases shown in this paper, and gives a conservative estimate of antenna performance over a wide range of installation and operational conditions.

Discussions with aviation antenna suppliers have shown that it is feasible to create an antenna with perhaps 2 dB of gain in the forward direction, without creating unwanted nulls in the antenna pattern. This antenna could be used to increase the range for deconfliction planning, where the primary need is for aircraft that lie ahead along the desired flight path. This gain antenna could be used on the aircraft topside. The normal omnidirectional antenna of uniform gain would be used on the bottom of the aircraft, to support uniform performance for air-to-ground surveillance.

Use of gain antennas for ADS-B is permitted and discussed in DO-242 (ADS-B MASPS) Section 3.3.1 and Appendix H.

Receiver Sensitivity threshold:

Based on lab measurements of the performance of the RS(45,33) Long ADS-B message, the link budget threshold for received signal strength is set at –94 dBm for 90% Message Success Rate (MSR). The proposed RS(45,33) code was measured to give approximately 1 to 1.5 dB better performance than the RS(41,35) code that is used for the Long ADS-B message in the Capstone equipment.

The same receiver sensitivity threshold is used for all equipment classes. This supports the desire for successful reception of FIS-B and TIS-B uplink broadcasts, which would suffer if lower receiver sensitivity thresholds were utilized.

MASPS equipment classes and range requirements

The following table summarizes the range requirements for each equipment class (MASPS Table 3-2(a) and Section 3.3.1)

AVA = Aid to Visual Acquisition
CA = Conflict Avoidance
SAS = Separation Assurance and Sequencing
TCP = Flight Plan Deconfliction Planning

Note that B1 (Tx Only Aircraft) have range requirements equivalent to interactive aircraft of similar altitude and maximum speed.

Class	Description	Min Range (nmi)
A0	AVA	10
A1	A0 + CA	20
A2	A1 + SAS	40
A3	A2 + TCP	90, (120,150)
B1	Tx Only A/C	same as A0,A1,A2
B2	Gnd Vehicles	5
B3	Fixed Obstruction	10

The extended ranges for the A3 category are to support the MASPS “desired” range (A3+), and the current Eurocontrol criteria (A3++). Performance that exceeds these minimum ranges is acceptable.

Effective Radiated Power (ERP)

ERP is used as the standard measurement of aircraft transmitter signal, so that equipment manufacturers may if desired elect to specify the use of gain antennas or other techniques to achieve the desired link budget.

Link Budget Examples:
The link budget tables below illustrate how various combinations of transmitter output power, feedline loss, and antenna gain can be used to balance the link.

GA Aircraft class (A0/A1)

The following table represents the minimum link budget that meets the A0 and A1 requirements for Air-to-Air range. The minimum ERP necessary is 5 watts.

Air-to-Air ADS-B	Units	A0/A1/B1	Notes
Tx Power - EQPT	dBm	40.0	10 watts (min)
Feedline	dB	-3.0	
Tx Power - ANT	dBm	37.0	
Tx Antenna Gain	dB	0.0	**ERP = 5 W**
Path	nmi	33.0	
Path Loss	dB	-128.0	
Signal at Rx Ant	dBm	-91.0	
Rx Antenna Gain	dB	0.0	
Feedline	dB	-3.0	
Rx Signal - EQPT	dBm	-94.0	

The range requirement for A0 is 10 nmi, and A1 is 20 nmi. The link margin at the 20 nmi limit is about 5 dB.

High-end GA/Corporate Aircraft (A2)

The following represents the link budget for high-performance GA aircraft, which may operate at greater speed and altitude. The ADS-B equipment used in Capstone is typical of this performance level, and normally exceeds this link budget by a substantial margin. This is at least partially due to greater ERP from higher than minimum transmitter output power and lower installed feedline losses.

Air-to-Air ADS-B	Units	A2/B1	Notes
Tx Power – EQPT	dBm	44.0	25 watts (min)
Feedline	dB	-3.0	
Tx Power – ANT	dBm	41.0	
Tx Antenna Gain	dB	0.0	**ERP = 12.5 W**
Path	nmi	52.0	
Path Loss	dB	-132.0	
Signal at Rx Ant	dBm	-91.0	
Rx Antenna Gain	dB	0.0	
Feedline	dB	-3.0	
Rx Signal – EQPT	dBm	-94.0	

The range requirement for the A2 category is 40 nmi. A typical Capstone installation has 1 dB greater transmitter power, and 1 db less feedline loss on transmit and receive, for a total of 3 dB improvement in the link budget. This increases the typical air-air range to 75 nmi.

Jet Transport (A3++)

Two alternatives for the A3 class are provided. The goal of both cases is meet the 150 nmi Eurocontrol criteria. These cases are shown side-by-side for ease of comparison.

		200 watt (min) XMTR		**Gain Antennas**	
Air-to-Air ADS-B	**Units**	**Values**	**Notes**	**Values**	**Notes**
Tx Power – EQPT	dBm	53	200 W	49	80 W
Feedline	dB	-3		-3	
Tx Power – ANT	dBm	50.0		46.0	
Tx Antenna Gain	dB	0.0	**ERP= 100 W**	2.0	**ERP = 63 W**
Path	nmi	150.0		150.0	
Path Loss	dB	-141.2		-141.2	
Signal at Rx Ant	dBm	-91.2		-93.2	
Rx Antenna Gain	dB	0.0		2.0	
Feedline	dB	-3.0		-3.0	
Rx Signal - EQPT	dBm	-94.2		-94.2	

Other combinations and techniques are possible that create sufficient ERP and sensitivity while minimizing transmitter power requirements and feedline losses. This table serves to illustrate two of many possible alternatives. Note that a 200 watt transmitter will have well over double the cost of an 80 watt transmitter.

In the case with Gain Antennas, the assumption is that both aircraft are like-equipped with 2 dB forward gain antennas, in a nose-to-nose encounter. If the receiving aircraft uses a 0 dB omni antenna for reception (such as A2 class equipment), the 2 dB gain penalty equates to reducing the range to 120 nmi.

Surface Vehicle (B2)/Fixed Obstruction(B3)

This section investigates the possibility of a transmitter category that would meet both the Surface Vehicle (B2) and Fixed Obstruction (B3) class requirements. For both cases, the receiving unit is modeled as a standard receiver with 3 dB of feedline loss and no antenna gain.

Gnd-to-Air ADS-B	Units	B2/B3 0.5 W @ Ant	Notes
Tx Power - EQPT	dBm	30	1 watt
Feedline	dB	-2	
Tx Power - ANT	dBm	28.0	
Tx Antenna Gain	dB	1.0	**ERP = 0.8 W**
Path	nmi	13.0	
Path Loss	dB	-119.9	
Signal at Rx Ant	dBm	-90.9	
Rx Antenna Gain	dB	0.0	
Feedline	dB	-3.0	
Rx Signal - EQPT	dBm	-93.9	

B2 has a 5 nmi range requirement, and B3 has a 10 nmi range requirement. A single transmitter type would meet both requirements. For the Fixed Obstruction transmitter, further performance improvement would be possible by use of a higher gain transmitter antenna, such as types suitable for Fixed Wireless ground stations.

For the Surface Vehicle case, some reduction in transmitter power could be tolerated and still meet the 5 nmi requirement. In addition, Land Mobile gain antennas are readily available and economical. For example, a 5/8 wave omnidirectional antenna with a 0.5 watt transmitter yields a **0.5 watt ERP**, which meets the 5 nmi requirement with 6 dB of margin to combat fading effects.

Conclusion

These examples have highlighted the minimum link budgets for compliance with MASPS range requirements. ERP can effectively be used to specify the transmitted signal. In addition, the link budget should allow for the effects of receiver antenna gain.