International Civil Aviation Organization

WORKING PAPER

SP3-ASWG8-WP/31
24/9/2018

THIRD MEETING OF THE SURVEILLANCE PANEL (SP/3)

Eighth meeting of the Aeronautical Surveillance Working Group (ASWG/8)

Montreal, Canada, 24 – 28 September 2018

SP3 Agenda item 3: Aeronautical surveillance systems and Airborne Collision Avoidance systems

ASWG8 Agenda Item 6: Mode S and Extended Squitter

Initial analysis of possible impact of small UAS transmitting on 1090MHz in Europe

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SUMMARY

This paper provides some initial results of the modelling of the impact of small UAS transmitting on 1090 MHz.

ACTION

The SP3-ASWG/8 is invited to:

a) Note the information contained in this WP and
b) To develop a common understanding of the impact of small UAS transmitting on 1090 MHz.

1. INTRODUCTION

1.1 There are ongoing discussions on whether small UAS could use 1090 MHz ADS-B to report their position.

1.2 EUROCONTROL is performing a study to investigate what would be the impact of ADS-B equipped SUAS operation on Mode S aircraft detection.

1.3 This paper presents some initial results of an investigation of the possible impact of the use of 1090 MHz by small UAS and asks the group to further review this subject in order to have a common understanding.

2. DISCUSSION

2.1 A RF model has been used to investigate the possible impact of transmissions on 1090 MHz from small UAS. The model has used some assumptions on transmissions that could be made by small UAS including their density and their transmitted power. Using these assumptions the model has looked at the impact on the reception of an ADS-B extended squitter transmitted by a normal aircraft, more particularly on the range reduction to keep the same level of probability of update of an ADS-B position.

2.2 The RF model has used different air environments coming from a real situation on a peak day in 2016 and a future environment with increased traffic (2025 scenario) together with 2016-ground infrastructure. The airborne scenarios are based on the surveillance radar data recordings for Friday 09/09/2016 at 09:15 UTC. Friday 09/09/2016 was a peak day in Europe with 35,594 flights. The study has looked at 3 air scenarios:

- 2016-CDG: one omni-directional antenna located at Charles de Gaulle (CDG) airport seeing 567 aircraft at -84dbM with a 7dB gain.

- 2016-FRA: one omni-directional antenna located close to Frankfurt (FRA) airport seeing 583 aircraft at -84dbM with a 7dB gain.

- 2025-FRA: one omni-directional antenna located close to Frankfurt (FRA) airport seeing 807 aircraft at -84dbM with a 7dB gain. It was build using STATFOR predictions and corresponds to 20% additional traffic.

2.3 In a first step, the study has looked at the impact on the decoding of an aircraft by a ground receiver surrounded by a set of small UAS. Additional steps are foreseen to look at different places in Europe and to look at the reception of an aircraft flying other a small UAS cloud.

2.4 The RF model used a degarbling performance as specified in ED-102A/DO-260B and a power gain of 7dB to not be limited by the distance (132NM without gain). As a consequence the obtained maximum range must be taken with precaution however the shape of the curves of probability of update remains the same.

2.5 The probability of update between 80 and 100NM obtained with the model for the CDG scenario is equivalent to the probability of update between 80 and 100NM measured on the Bretigny ADS-B station at another rdate.

2.6 The transmission rates of ADS-B extended squitters was set at:

- 5.6/s for each aircraft in the air,
- 2.2/s on average for aircraft on the ground (weighted average between 2.6/s moving and 0.5/s not moving),
- 4.6/s for DF18 rate from SUAS is set to 4.6 in the RF Model:
  - 2 Airborne Position / sec
  - 0.2 ACID / sec
  - 2 Airborne Velocity / sec
  - 0.4 Aircraft Operational Status / sec

2.7 The approach used was to look at the delta performance created by the addition of the new transmissions generated by the small UAS (SUAS).

2.8 The variables that were used during the modelization are:

- the density of small UAS around the receiver,
- the power transmitted by small UAS.

2.9 The UAS density is no known with certitude therefore different small UAS densities have been used as specified the table below. A case was reported in Germany with 1000 drones detected in the Hamburg CTR.

SUAS Scenario	SUAS Density (number of SUAS per Km^2 (/NM^2))	ADS-B Output Power	Number of SUAS detected by the omni-directional antenna at -84 dBm	Max range of UAS received at -84dBm in NM with 7db gain
1	**0.5 (1.75)**	**0.1W (20dBm)**	**93**	**4.2**
2	**1 (3.5)**	**0.1W (20dBm)**	**390**	**4.2**
3	**3 (10.5)**	**0.1W (20dBm)**	**563**	**4.2**
4	**0.5 (1.75)**	**1W (30dBm)**	**933**	**13.3**
5	**1 (3.5)**	**1W (30dBm)**	**1898**	**13.3**
6	**3 (10.5)**	**1W (30dBm)**	**5736**	**13.3**

Table 1 – SUAS Environments

2.10 The range for different received level is given for different powers in the following graph when using a 7dB antenna gain.

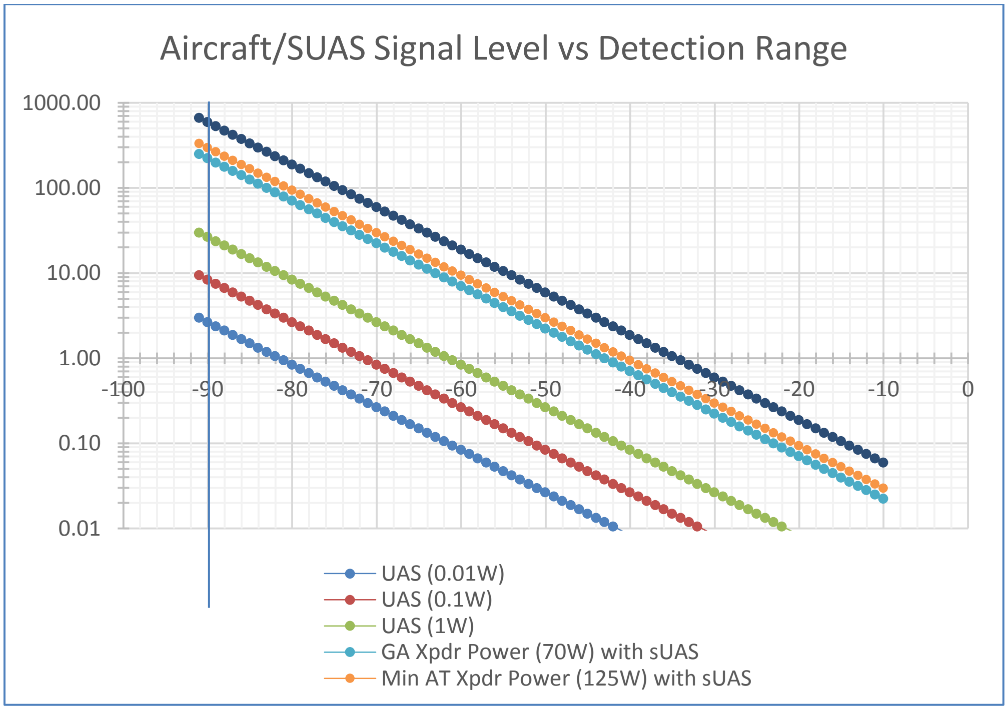

Figure 1 – Detection range for -84dbm with + 7 db gain for different transmitted powers

2.11 The study looked at the decoding probability of a signal S transmitted by one aircraft. The interfering signals could come from other aircraft using high powers therefore located in a large area (green star) or from systems using lower transmission power such as small UAS contained in a smaller volume around the receiver (blue circles).

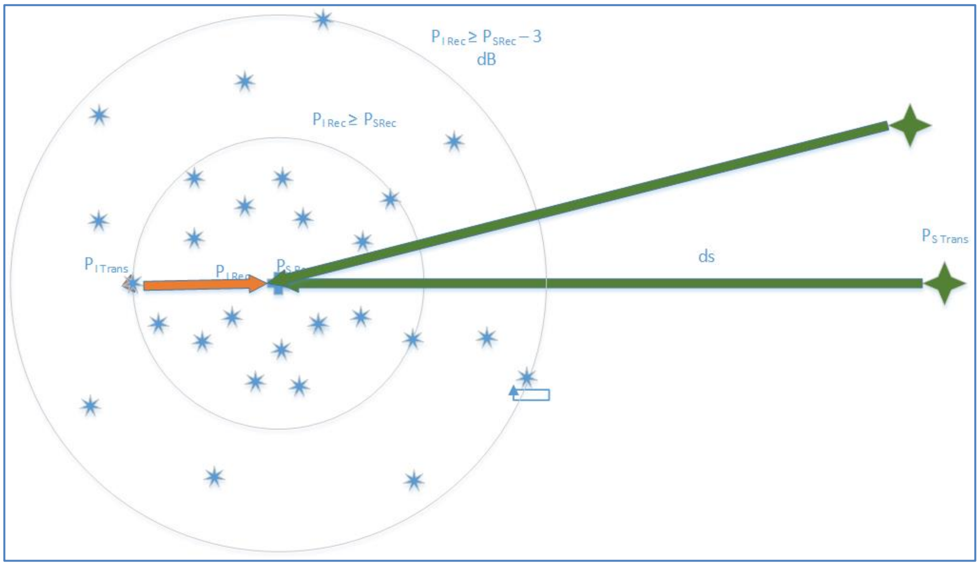

Figure 2 – SUAS cloud impacting the detection of a transmission from 1 aircraft

2.12 For example using the previous graph an aircraft transmitting 500W (dark blue curve) located at 105NM is impacted by messages received at same power from small UAS transmitting 1W within 4.7 Nm around the receiver or by messages received at (power-3dB) from small UAS transmitting 1W within 6.7 NM .

2.13 Result for FRA-2016 1W 3UAS /km^2 – PoU 5s

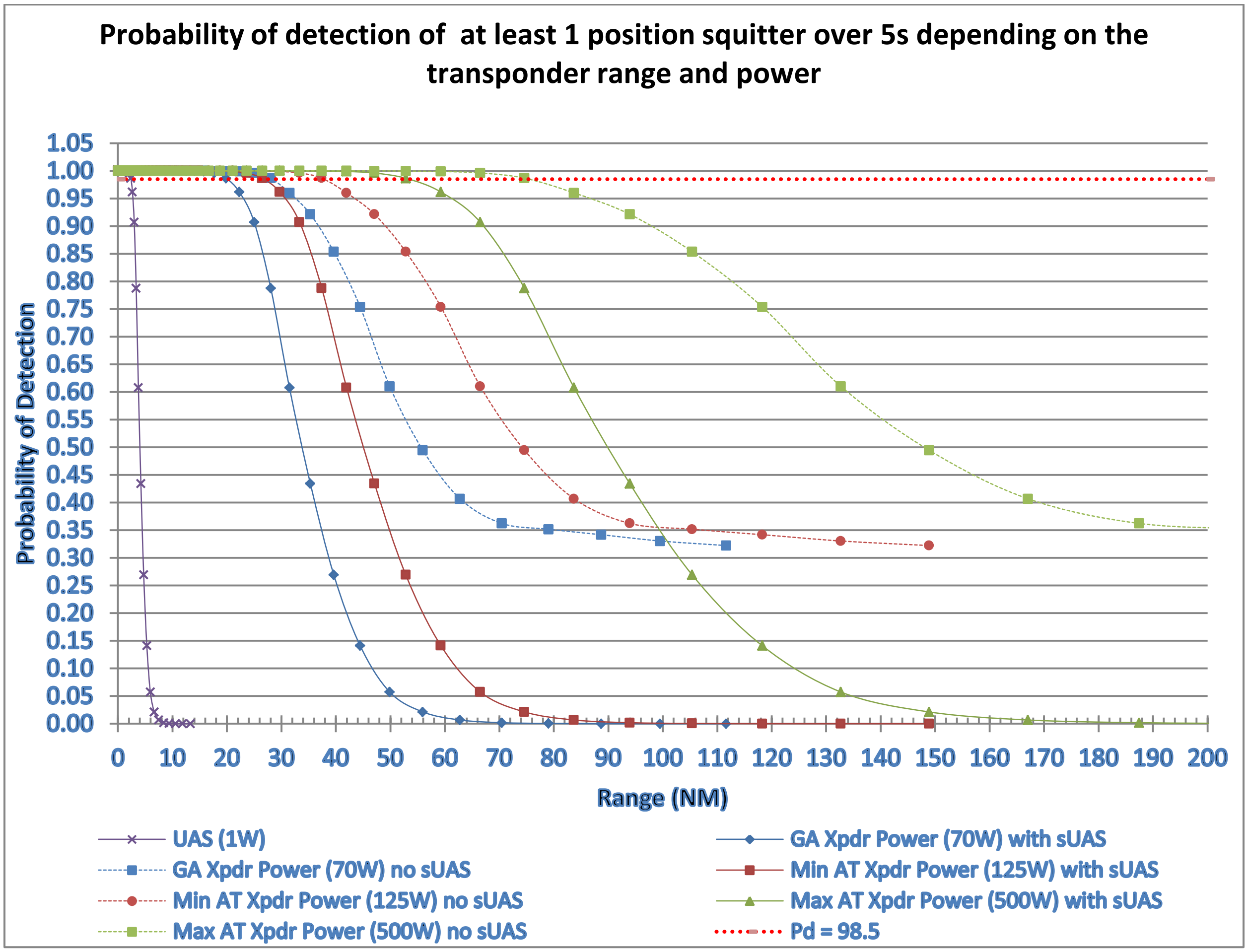

Figure 3 – Comparison probability of detection versus range no UAS – UAS over 5s – FRA 2016- 1W – 3UAS

2.14 The range of aircraft/SUAS to get a probability of detection = 98.5 is:

- 75.3NM for Air Transport with max transponder power NO SUAS
- 53.3NM for Air Transport with max transponder power - with SUAS 1W

  ➔ **Range reduction = 22NM**

- 37.7NM for Air Transport with min transponder power – NO SUAS
- 26.7NM for Air Transport with min transponder power – with SUAS 1W

  ➔ **Range reduction = 11NM**

- 28.3NM for General Aviation – NO SUAS
- 20NM for General Aviation – with SUAS 1W

  ➔ **Range reduction = 8.3NM**

- 2.4NM for SUAS 1W

2.15 This scenario, 1W and 3UAS per km2, creates a big range reduction.

2.16 Result for FRA-2016 0.1W 3UAS /km^2 – PoU 5s

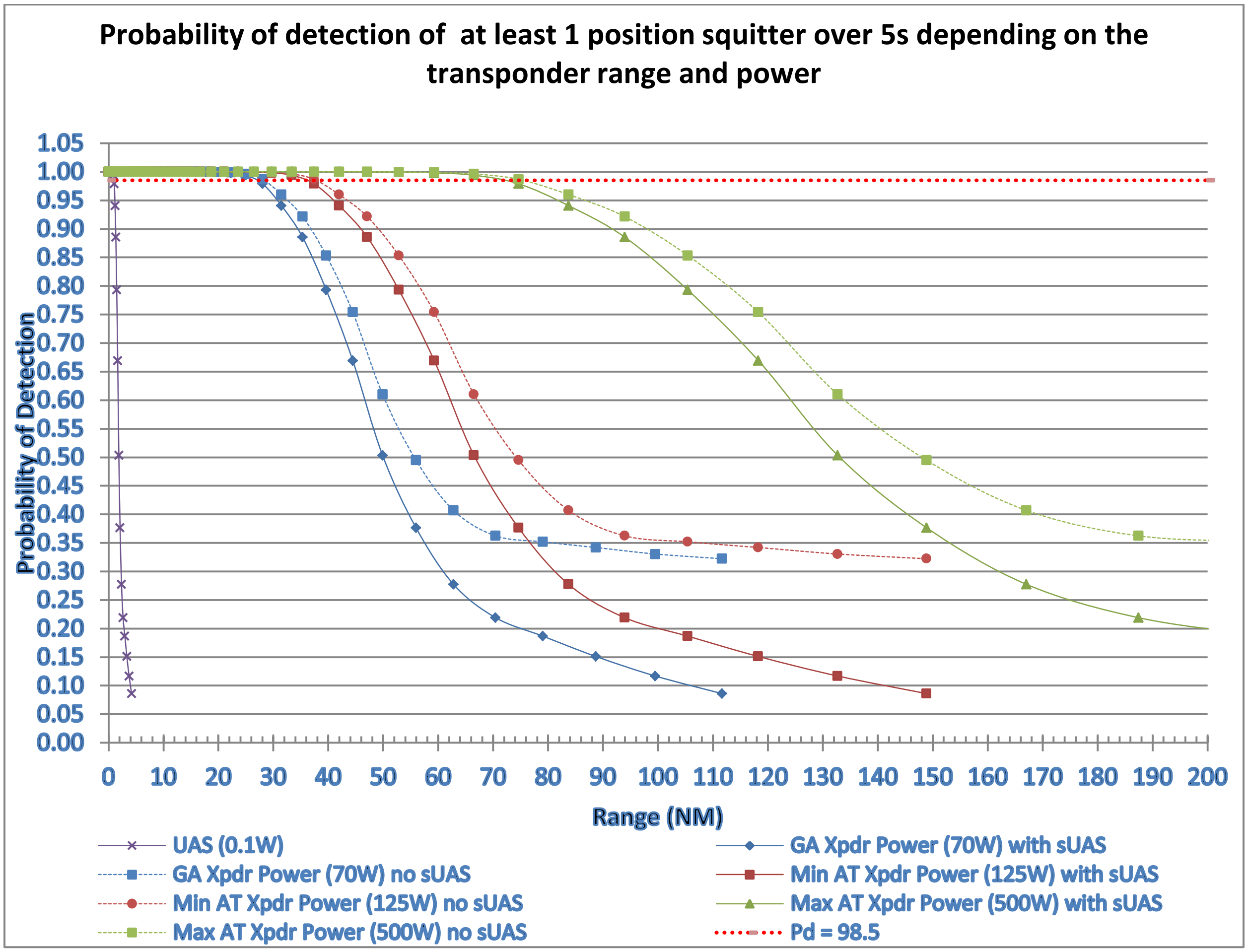

Figure 4 – Comparison probability of detection versus range no UAS – UAS over 5s – FRA 2016- 0.1W - 3UAS

2.17 The range of aircraft/SUAS to get a probability of detection = 98.5 is provided below:

- 75.3NM for Air Transport with max transponder power - NO SUAS
- 71.4NM for Air Transport with max transponder power - with SUAS 0.1W
  - ➔ **Range reduction = 3.9NM**
- 37.7NM for Air Transport with min transponder power – NO SUAS
- 35.8NM for Air Transport with min transponder power – with SUAS 0.1W
  - ➔ **Range reduction = 1.9NM**
- 28.3NM for General Aviation – NO SUAS
- 26.8NM for General Aviation – with SUAS 0.1W
  - ➔ **Range reduction = 1.5NM**
- 1NM for SUAS 0.1W.

2.18 The reduction of the transmitted power has a big effect on the impact that is reduced a lot, from 22NM (1W) to only 3.9NM (0.01W).

2.19 Result for FRA-2016 1W 1UAS /km^2 – PoU 5s

If the number of small UAS is reduced to 1/km^2 The figure below provides the probability of detection of at least 1 position squitter per 5 second period

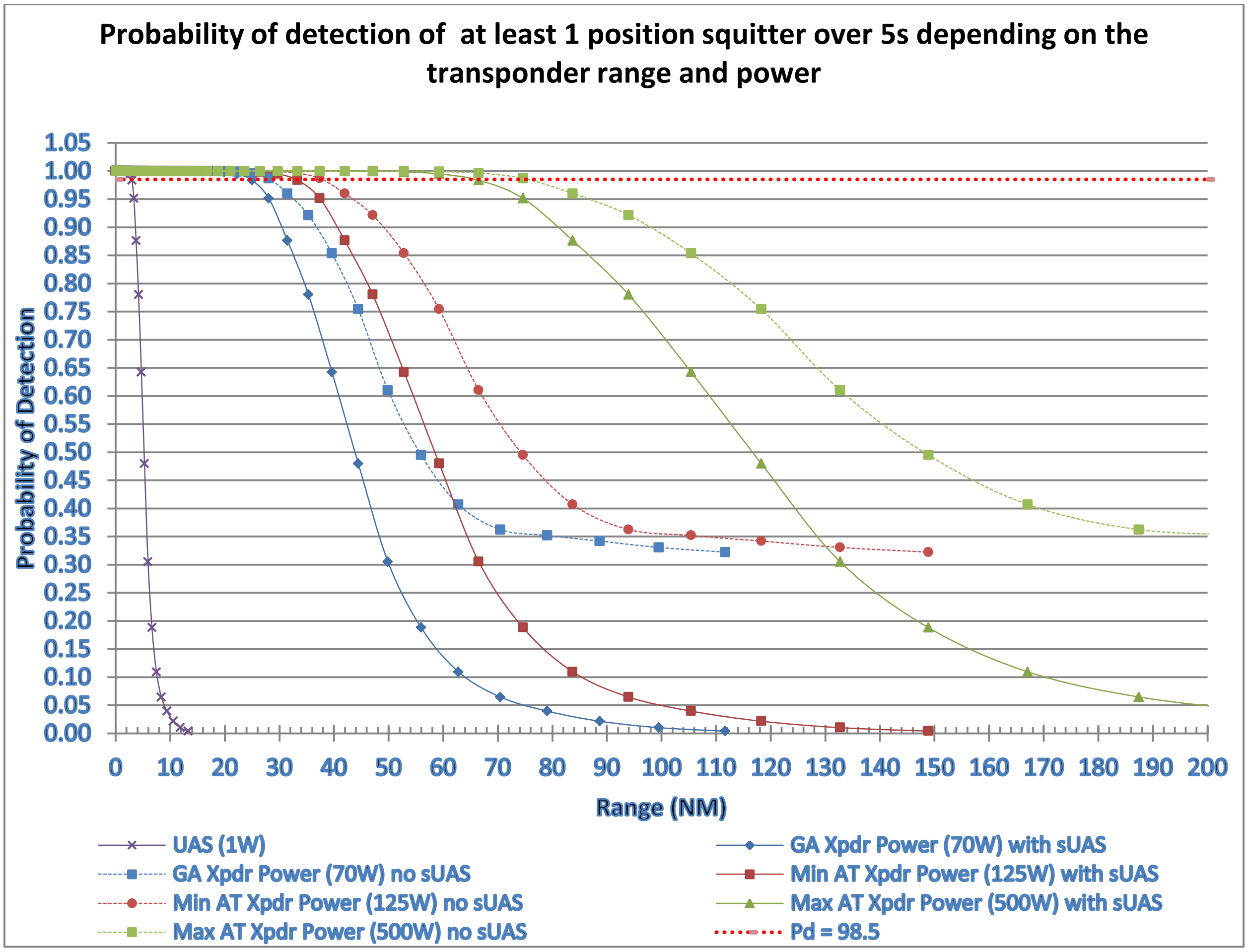

Figure 5 – Comparison probability of detection versus range no UAS – UAS over 5s – FRA 2016- 1W – 1UAS

2.20 The range of aircraft/SUAS to get a probability of detection = 98.5 is provided below:

- 75.3NM for Air Transport with max transponder power - NO SUAS
- 65.6NM for Air Transport with max transponder power - with SUAS 1W

  ➔ **Range reduction = 9.7NM**

- 37.7NM for Air Transport with min transponder power – NO SUAS 1W
- 32.9NM for Air Transport with min transponder power – with SUAS

  ➔ **Range reduction = 4.8NM**

- 28.3NM for General Aviation – NO SUAS
- 24.6NM for General Aviation – with SUAS 1W

  ➔ **Range reduction = 3.7NM**

- 2.9NM for SUAS 1W

2.21 Reducing the small UAS density from 3 to 1 /km^2 has also a big impact alleviating the performance reduction from 22NM to 9.7 NM reduction in range.

2.22 Result For CDG-2016 1W 3UAS /km2 – PoU 5s

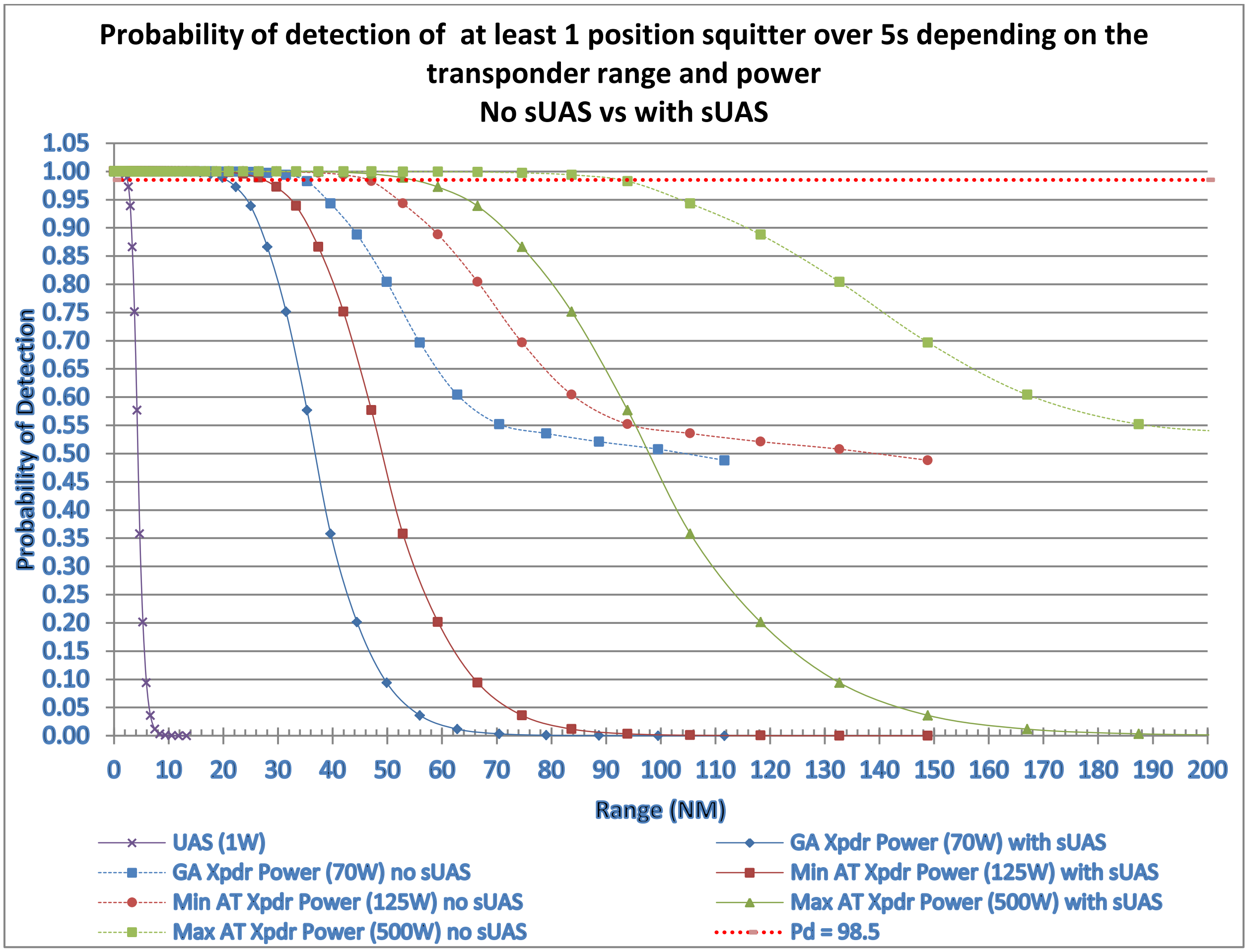

Figure 6 – Comparison probability of detection versus range no UAS – UAS over 5s – CDG 2016- 1W

2.23 The range of aircraft/SUAS to get a probability of detection = 98.5 is provided below:

- 91.8NM for Air Transport with max transponder power - NO SUAS
- 54.3NM for Air Transport with max transponder power - with SUAS 1W

  ➔ **Range reduction = 37.5NM**

- 46NM for Air Transport with min transponder power – NO SUAS
- 27.2NM for Air Transport with min transponder power – with SUAS 1W

  ➔ **Range reduction = 18.8NM**

- 34.5NM for General Aviation – NO SUAS
- 20.4NM for General Aviation – with SUAS 1W

  ➔ **Range reduction = 14.1NM**

- 2.4NM for SUAS 1W

2.24 The impact of 3 small SUAS/km^2 transmitting at 1W is in proportion more important in area with low traffic density. However, the achieved range is similar to what is estimated in higher density areas, 53.3 NM at FRA to be compared to 54.3NM in CDG area.

2.25 Result for FRA-2025 1W 1UAS /km2 – PoU 5s

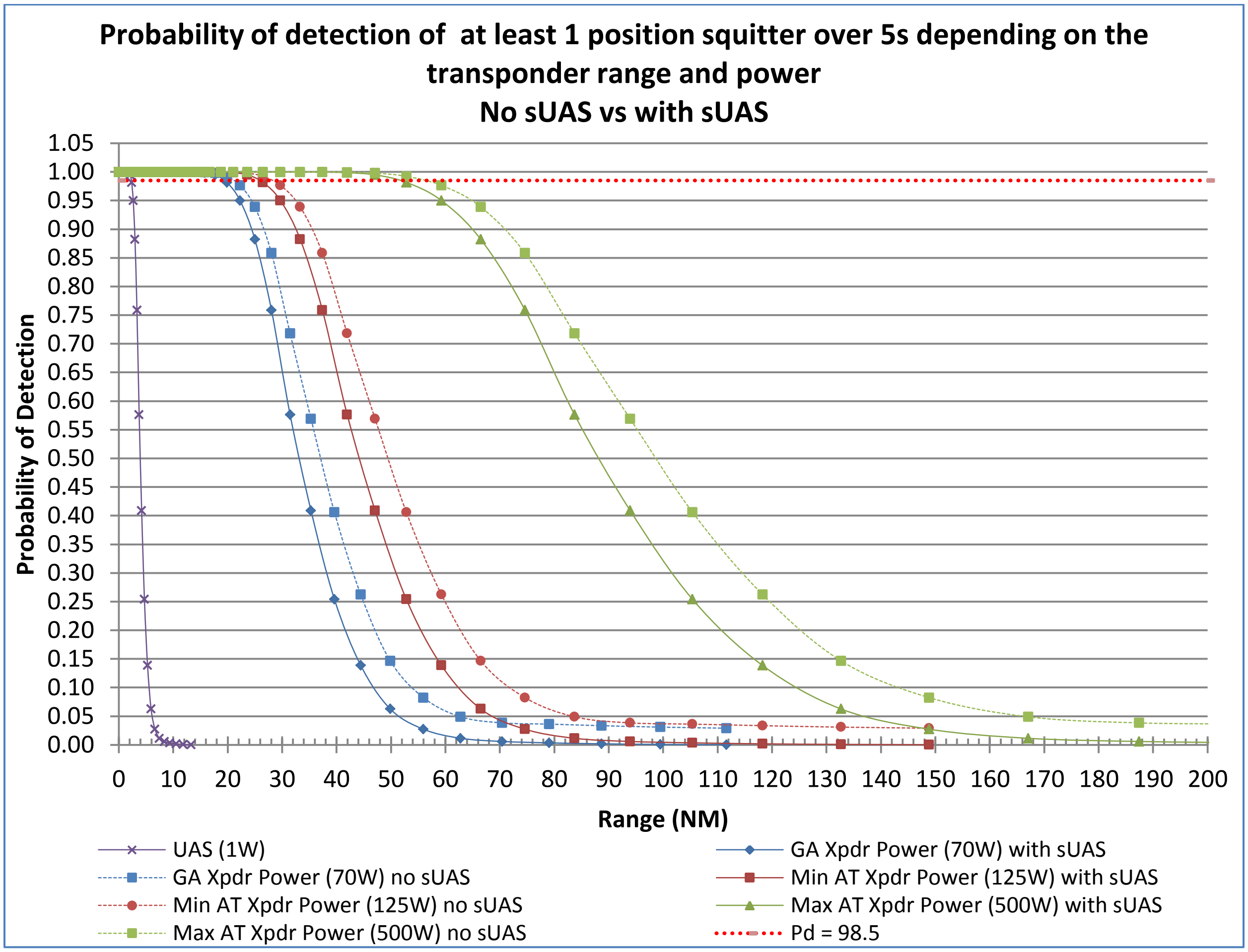

Figure 7 – Comparison probability of detection versus range no UAS – UAS over 5s – FRA 2025- 1W

2.26 The range of aircraft/SUAS to get a probability of detection = 98.5 is provided below:

- 51.4NM for Air Transport with max transponder power - with SUAS 1W
- 55.8NM for Air Transport with max transponder power - NO SUAS

  ➔ **Range reduction = 4.4NM**

- 25.8NM for Air Transport with min transponder power – with SUAS 1W
- 28.0NM for Air Transport with min transponder power – NO SUAS

  ➔ **Range reduction = 2.2NM**

- 19.3NM for General Aviation – with SUAS 1W
- 21NM for General Aviation – NO SUAS

  ➔ **Range reduction = 1.6NM**

- 2.3NM for SUAS 1W

2.27 UAS transmission on 1090 has less impact (e.g 4.4NM) in the future when the range reduction will be first generated by the additional aircraft transmissions.

3. SUMMARY

3.1 The table 2 compares the maximum detection range of aircraft and SUAS to get a probability of update of 98.5% over a 5 second period.

	Max detection range (in NM) **PD of 1 position squitter in 5 second = 98.5%** **(Range Reduction in % compared to the scenario with NO SUAS)**			
SUAS Scenario	SUAS	GA Transponder Power 46dBm - 70W	Min Air Transport Transponder Power 51dBm - 125W	Max Air Transport Transponder Power 57dBm - 500W
FRA 2016 - NO SUAS	**N/A**	**28.3**	**37.7**	**75.3**
FRA 2016 - 1	1.1 (0.1W)	28.1 (0.71%)	37.5 (0.53%)	74.9 (0.53%)
FRA 2016 - 2	1.1 (0.1W)	27.9 (1.41%)	37.2 (1.33%)	74.3 (1.33%)
FRA 2016 - 3	1 (0.1W)	26.8 (5.30%)	35.8 (5.04%)	71.4 (5.18%)
FRA 2016 - 4	3.1 (1W)	26.1 (7.77%)	34.8 (7.69%)	69.4 (7.84%)
FRA 2016 - 5	2.9 (1W)	24.6 (13.07%)	32.9 (12.73%)	65.6 (12.88%)
FRA 2016 - 6	2.4 (1W)	20 (29.33%)	26.7 (29.18%)	53.3 (29.22%)
CDG 2016 - NO SUAS	**N/A**	**34.5**	**46**	**91.8**
CDG 2016 - 1	1.3 (0.1W)	34 (1.45%)	45.3 (1.52%)	90.4 (1.53%)
CDG 2016 - 2	1.3 (0.1W)	33.5 (2.90%)	44.6 (3.04%)	89 (3.05%)
CDG 2016 - 3	1.2 (0.1W)	32 (7.25%)	42.7 (7.17%)	85.1 (7.30%)
CDG 2016 - 4	3.6 (1W)	30.4 (11.88%)	40.6 (11.74%)	81 (11.76%)
CDG 2016 - 5	3.3 (1W)	27.4 (20.58%)	36.6 (20.43%)	73 (20.48%)
CDG 2016 - 6	2.4 (1W)	20.4 (40.87%)	27.2 (40.87%)	54.3 (40.85%)
FRA 2025 - NO SUAS	**N/A**	**21**	**28**	**55.8**
FRA 2025 - 1	0.8 (0.1W)	20.9 (0.48%)	27.8 (0.71%)	55.5 (0.54%)
FRA 2025 - 2	0.8 (0.1W)	20.8 (0.95%)	27.7 (1.07%)	55.2 (1.08%)
FRA 2025 - 3	0.8 (0.1W)	20.4 (2.86%)	27.3 (2.50%)	54.4 (2.51%)
FRA 2025 - 4	2.4 (1W)	20.2 (3.81%)	26.9 (3.93%)	53.6 (3.94%)
FRA 2025 - 5	2.3 (1W)	19.3 (8.10%)	25.8 (7.86%)	51.4 (7.89%)
FRA 2025 - 6	Not run			

Table 2 – Max detection range – PD=98.5% at 5s

3.2 The following graph represents the ranges for the reception of message transmitted from 500W and 70 W transponders.

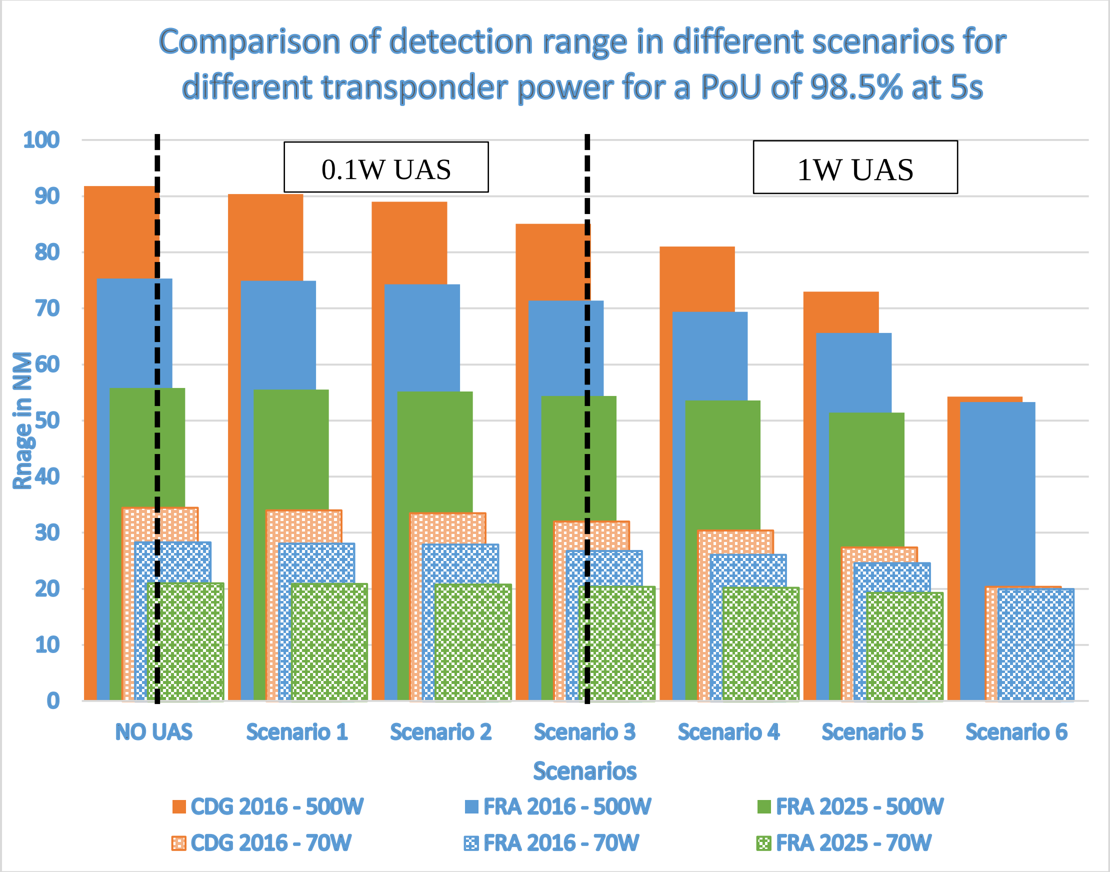

Figure 8 – Comparison of detection range in different scenarios for different transponder power for a PoU of 98.5% at 5s

3.3 In all cases, the addition of UAS transmission on 1090 results in a range reduction of the ADS-B ground station to maintain the same probability of update (98.5%).

3.4 For 0.1W power transmission, the range reduction is up to 3% for scenario with 1 UAS /km2 and up to 8% for scenario with 3UAS/km^2. This might be considered as “limited impact” although it will increase the cost of ground ADS-B receiver network.

3.5 For 1W power transmission, the range reduction is more important going up to 41% for 5s and 38% for a 8s update interval in CDG environment (scenario 6). This is a large reduction however for scenario5 (1UAS/km2) at 5s update period the range of CDG remains at a value similar to the range of an ADS-B at Frankfurt in 2016 without UAS.

3.6 The environments with a higher number of aircraft (high density of aircraft) are “less visible” by the ADS-B broadcast by SUAS.

3.7 The impact should be further investigated for other scenarios including airborne 1090 receivers.

4. ACTION BY THE MEETING

4.1 The SP/3-ASWG/8 is invited to:

a) Note the initial results of a study investigating the impact of small UAS transmitting on 1090 MHz with up to 40% reduction of reception range depending on scenario,

b) Note that a better definition of scenarios and more analyses are required,

c) task the TSG to develop a common understanding of the impact of small UAS transmitting on 1090 MHz.

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