Impact of SUAS ADS-B on 1090MHz

Surveillance/MICA Workshop

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Study Purpose and Environment

- Investigate the impact of ADS-B equipped SUAS (Small Unmanned Aircraft Systems) operation on Mode S aircraft detection by omni-directional antenna
  - EUROCONTROL 1030/1090MHz RF Model is used

- Omni-directional antenna located close to Frankfurt (FRA) airport and at Charles de Gaulle (CDG) airport
- Ground environment based on MICA Cycle 24 (13/10/2016)
- Airborne environment based on the surveillance data recordings (Asterix Cat. 48) on 09/09/2016 at 09:15 UTC.
  - Friday 09/09/2016 was a peak day in Europe with 35,594 flights.
  - 2025 airborne environment extrapolated from 2016 environment
    - 20% more aircraft
    - All aircraft are Mode S and equipped with ADS-B out (DF17)

Study Hypothesis

- Detection by omni-directional antenna at MTL = -84dBm with 7dB gain

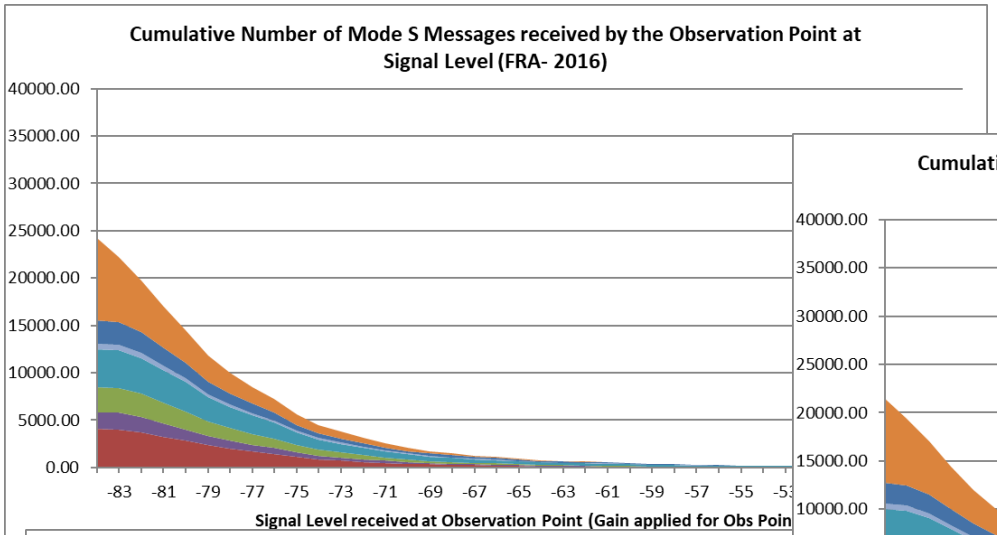
- 5.6 DF17 per second for aircraft in the air
- 2.2 DF17 per second for aircraft on the ground
- 4.6 DF18 per second for SUAS

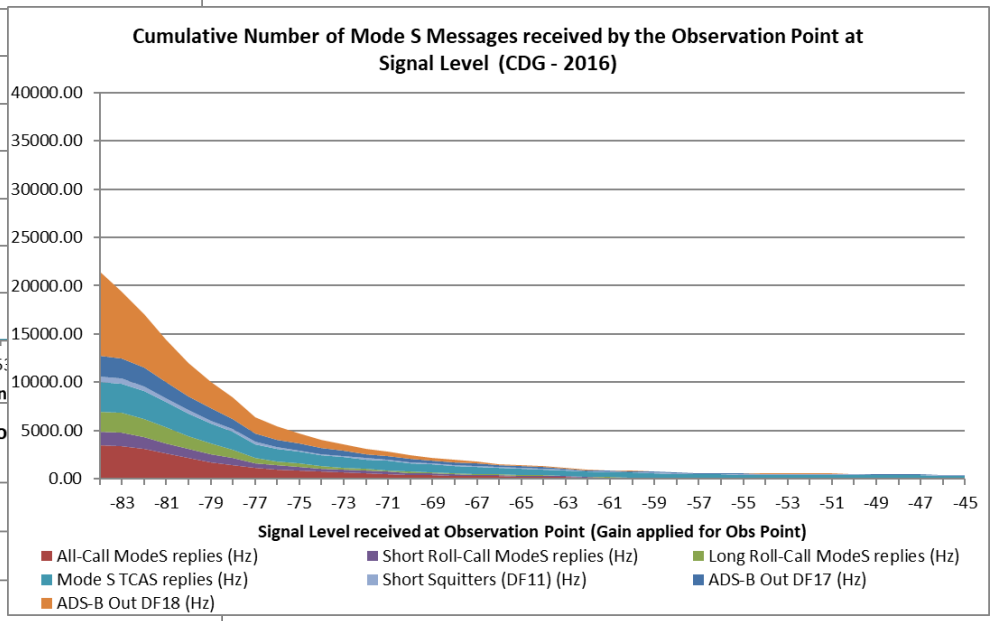
- Two main variables used to simulate the impact of SUAS ADS-B:
  - the power of SUAS transmission: 0.1W or 1W,
  - the density of SUAS: 0.5,1 or 3 SUAS per km^2.

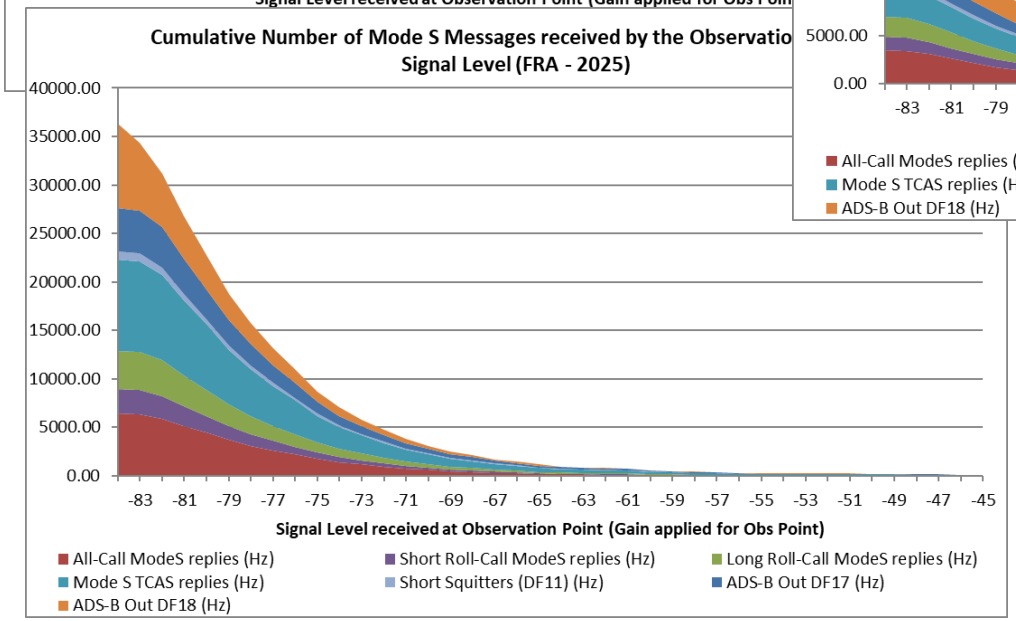
SUAS Scenario	SUAS Density (number of SUAS / Km²)	ADS-B Output Power	Number of SUAS detected by the omni-directional antenna at -84 dBm	Max range of SUAS received at -84dBm in NM
1	0.5 (1.75/NM²)	0.1W (20dBm)	93	4.2
2	1 (3.5/NM²)	0.1W (20dBm)	390	4.2
3	3 (10.5/NM²)	0.1W (20dBm)	563	4.2
4	0.5 (1.75/NM²)	1W (30dBm)	933	13.3
5	1 (3.5/NM²)	1W (30dBm)	1898	13.3
6*	3 (10.5/NM²)	1W (30dBm)	5736	13.3

*SUAS Scenario 6 not run on 2025 environment

Cumulative Mode S Message Rate







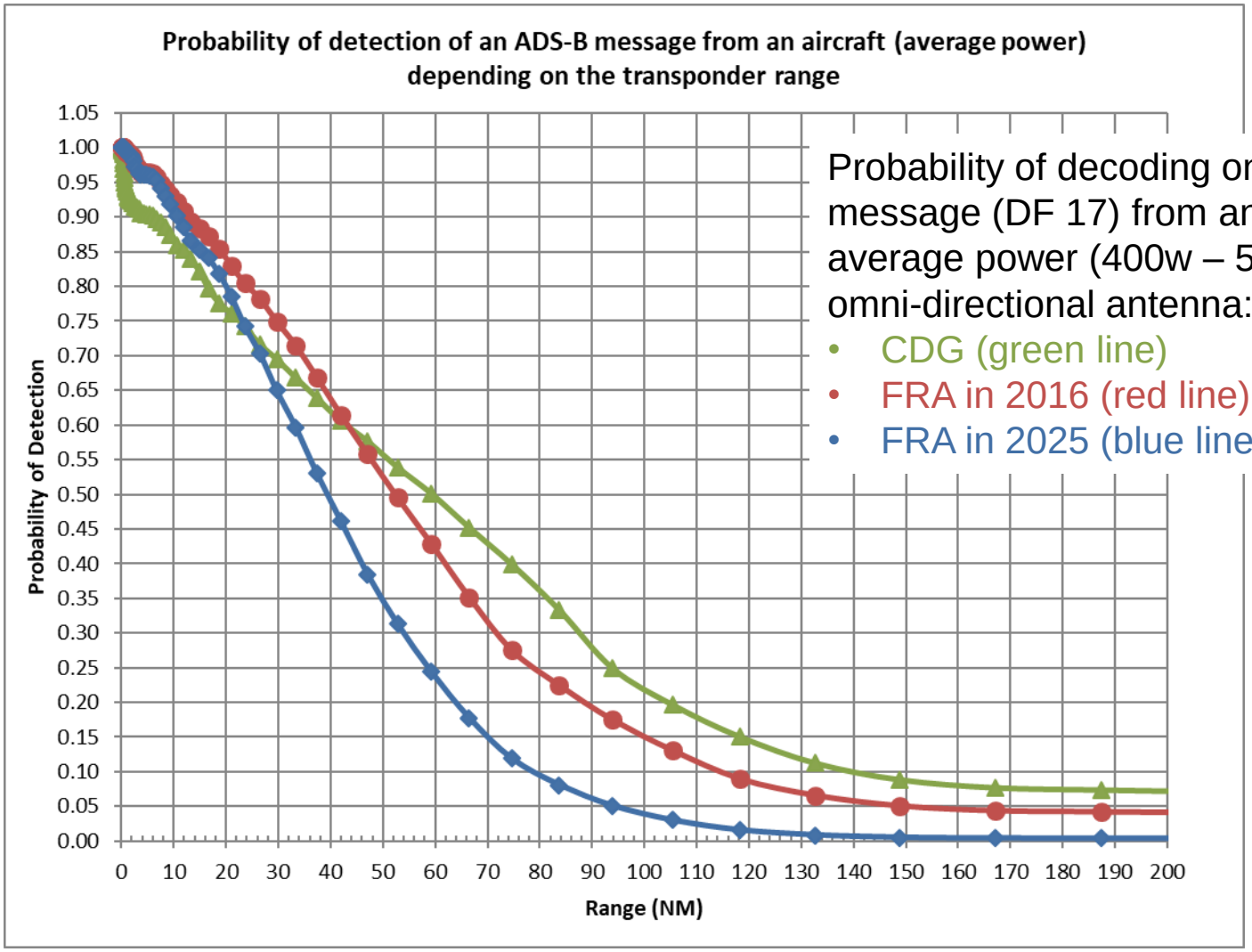
- ADS-B output power of SUAS set to 1W (30dBm)
- 1 SUAS per Km² (3.5 SUAS / NM²)
- SUAS only emit ADS-B DF18 messages (in orange in the graph).

Decoding Probability of Garbled Messages

- The RF model computes the probability of garbling of a Mode S long message (ADS-B message) with other Mode S messages (short or long Mode S messages).
  - The garbling with Mode A/C messages is not computed.
- ADS-B message garbled by Mode S messages having higher amplitude cannot be decoded.
- The decoding probability of ADS-B message garbled by Mode S messages having lower amplitude depends on the relative power according to Section 2.4.4.4.2.5 of DO-260B:

Relative Power (dB)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Decoding Probability	0	0	0.02	0.12	0.59	0.8	0.95	0.99

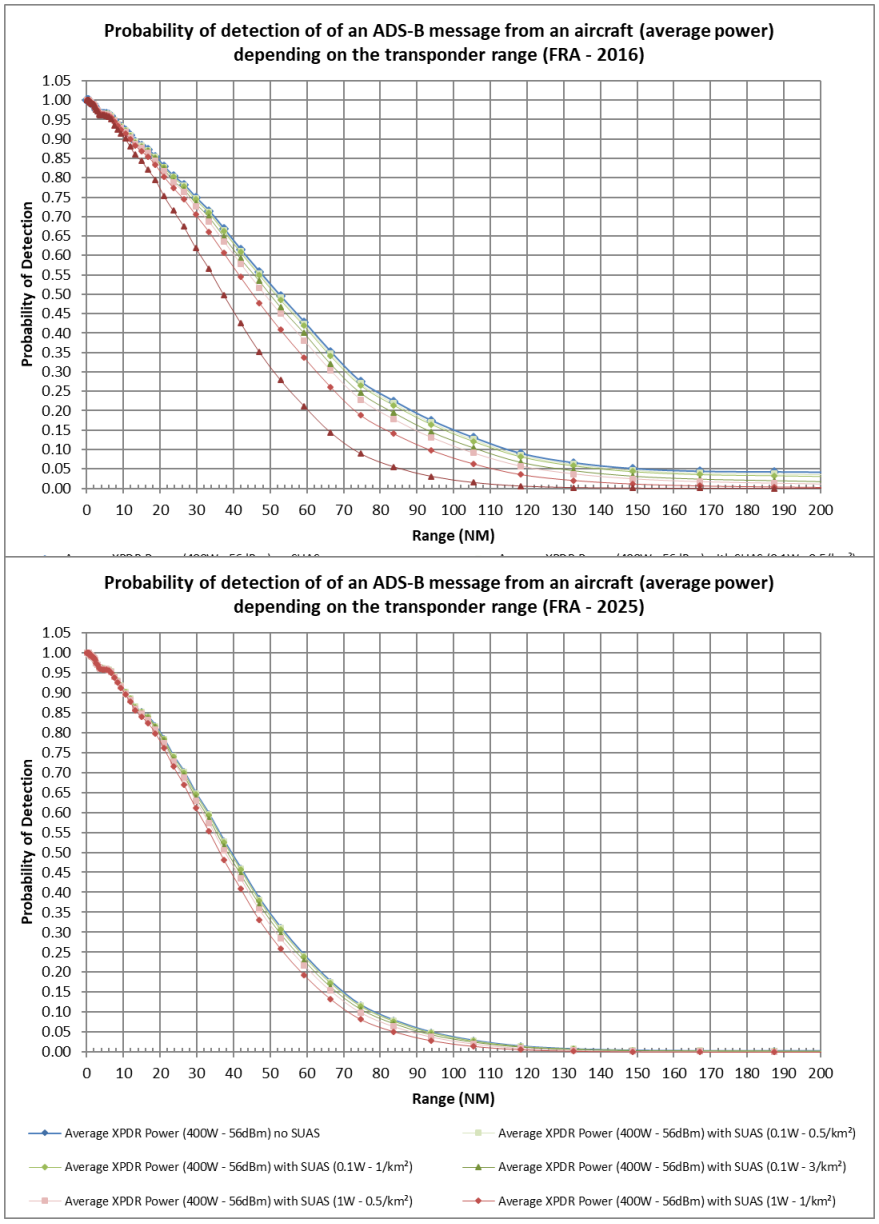
Probability of Decoding – No SUAS

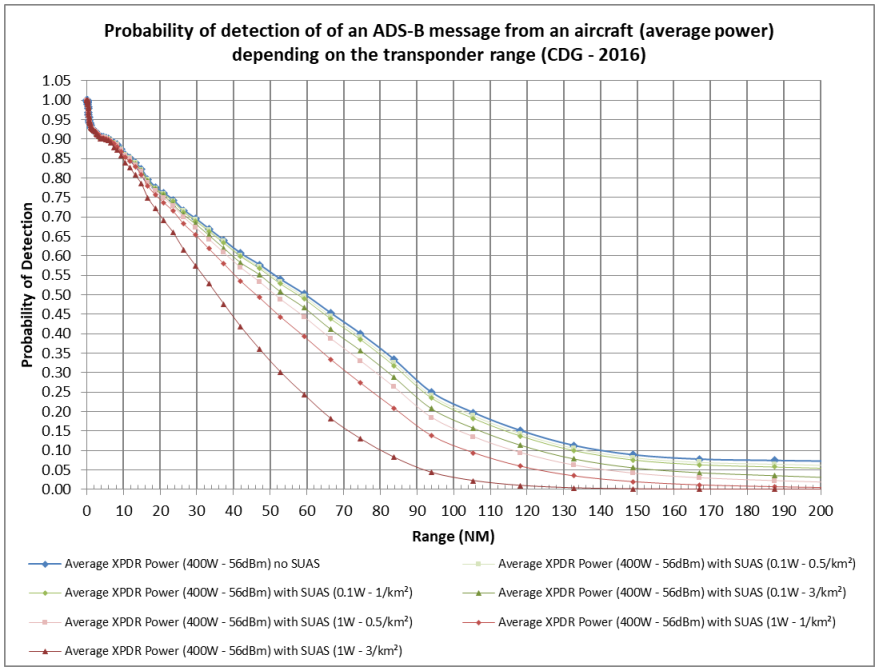


Probability of decoding one ADS-B message (DF 17) from an aircraft with average power (400w – 56dBm) by omni-directional antenna:

- CDG (green line)
- FRA in 2016 (red line)
- FRA in 2025 (blue line)

Probability of Decoding





Probability of decoding one ADS-B message (DF 17) from an aircraft with average power (400w – 56dBm) depending on

- aircraft range and
- SUAS environment (ADS-B output power and density)

Probability of Decoding vs Probability of Update

Example at CDG with no SUAS

Probability to decode a position squitter per second

- PD= 0.3335 at range = 83.72NM

Probability to decode at least one position squitter per second (2 position squitters per second) = 1 – probability to decode no position squitter per second

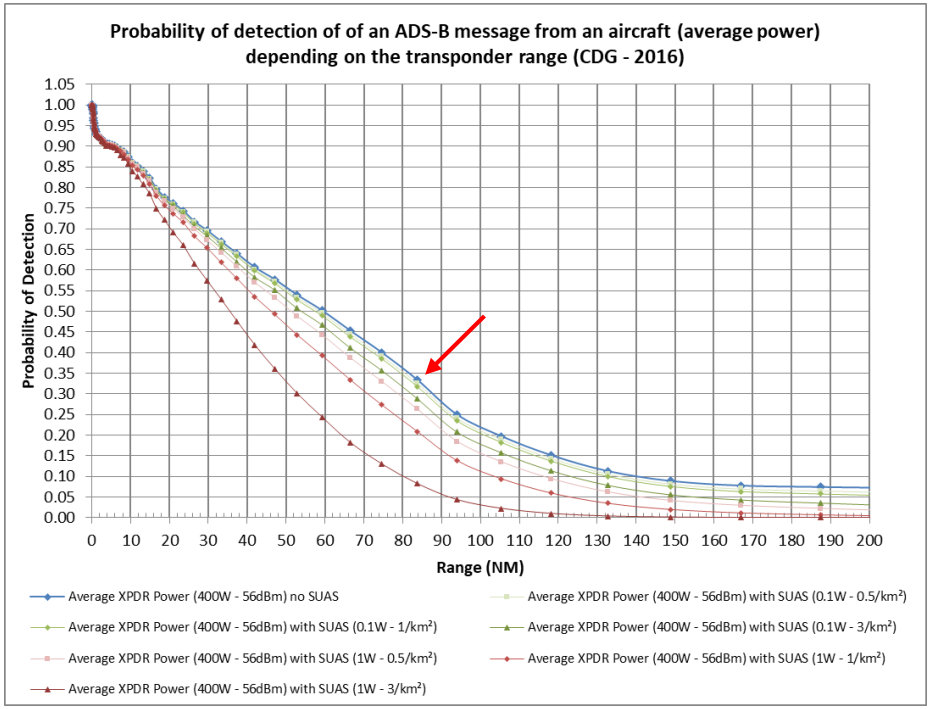
- 1 – ((1 – 0.3335) x (1- 0.3335)) = 0.5558

Probability to decode at least one position squitter per 5 second (probability of update on 5 sec)

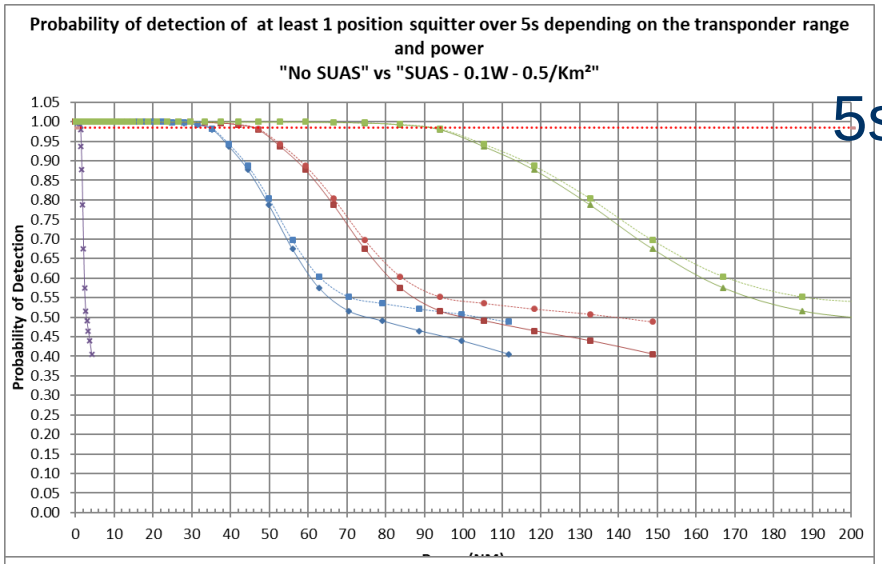
- 1 – 0.6665^10 = 0.9827

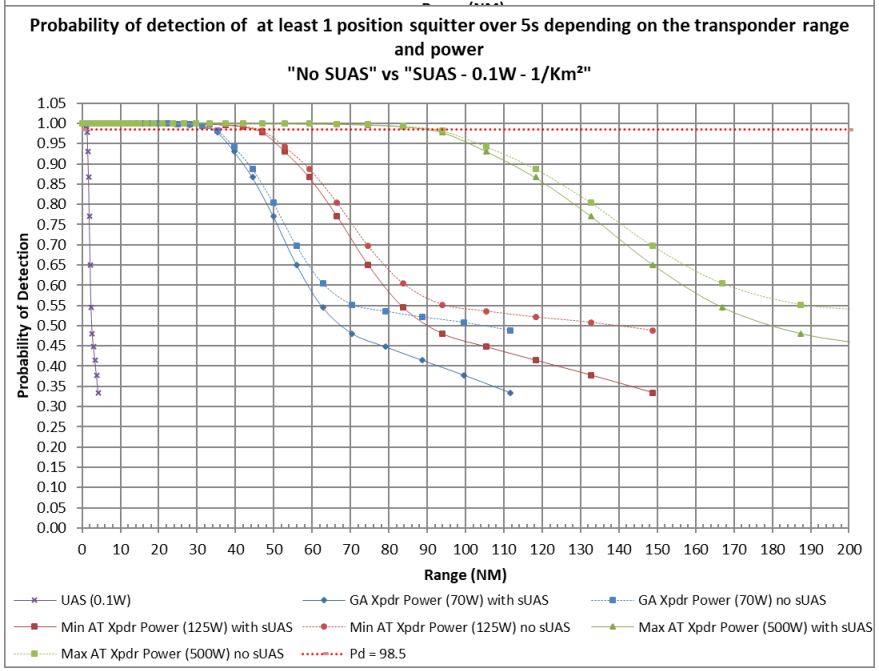
Probability to decode at least one position squitter per 8 second (probability of update on 8 sec)

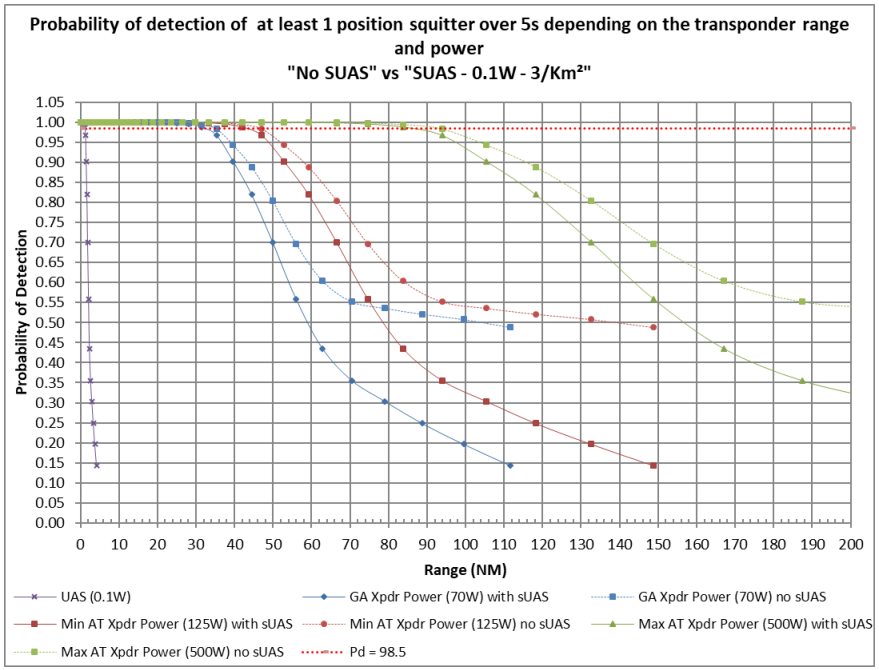
- 1 – 0.6665^16 = 0.9985



Probability of Update 5s – CDG 2016 – 0.1w

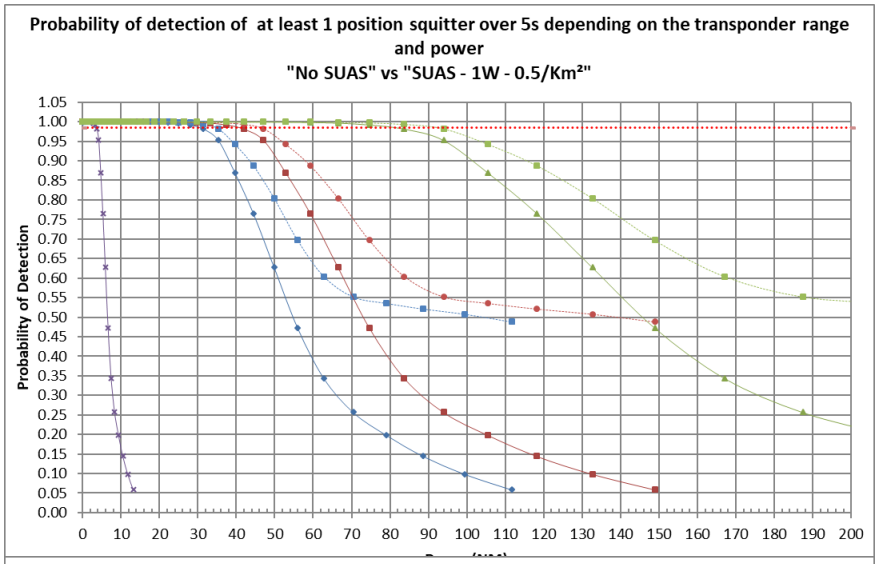


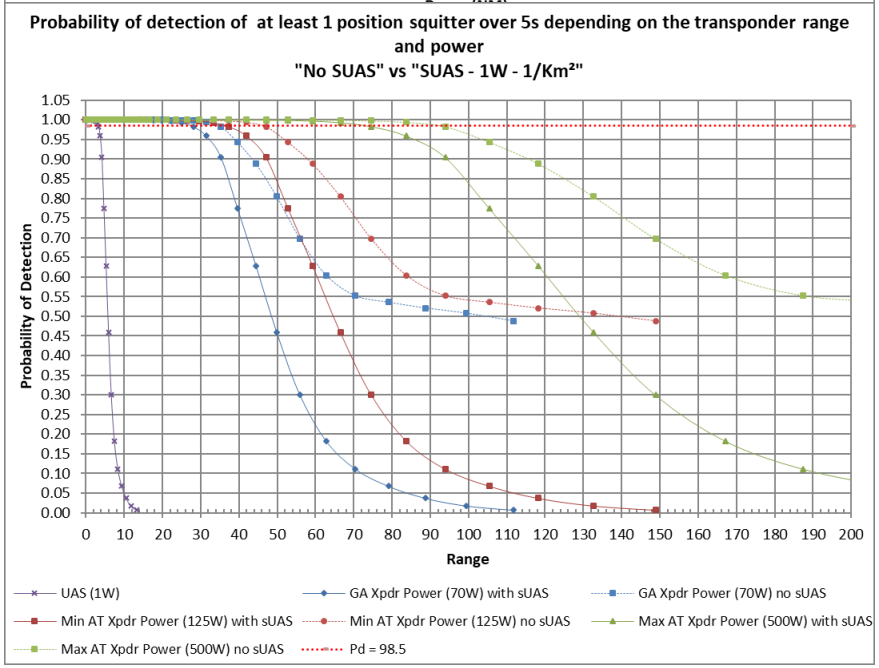




	Max detection range (in NM) PD of 1 position squitter in 5 second = 98.5%			
SUAS Scenario 0.1W	SUAS	GA Xpdr Power 46dBm - 70W	Min Air Transport Xpdr Power 51dBm - 125W	Max Air Transport Xpdr Power 57dBm - 500W
NO SUAS	**N/A**	**34.5**	**46**	**91.8**
0.5/Km²	1.3 (0.1W)	34 (1.45%)	45.3 (1.52%)	90.4 (1.53%)
1/Km²	1.3 (0.1W)	33.5 (2.90%)	44.6 (3.04%)	89 (3.05%)
3/Km²	1.2 (0.1W)	32 (7.25%)	42.7 (7.17%)	85.1 (7.30%)

Probability of Update 5s – CDG 2016 – 1w





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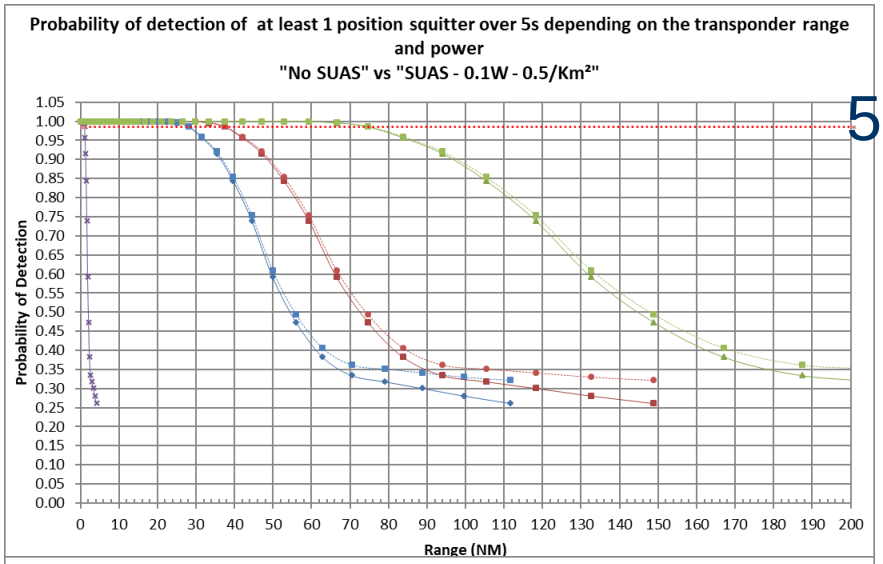
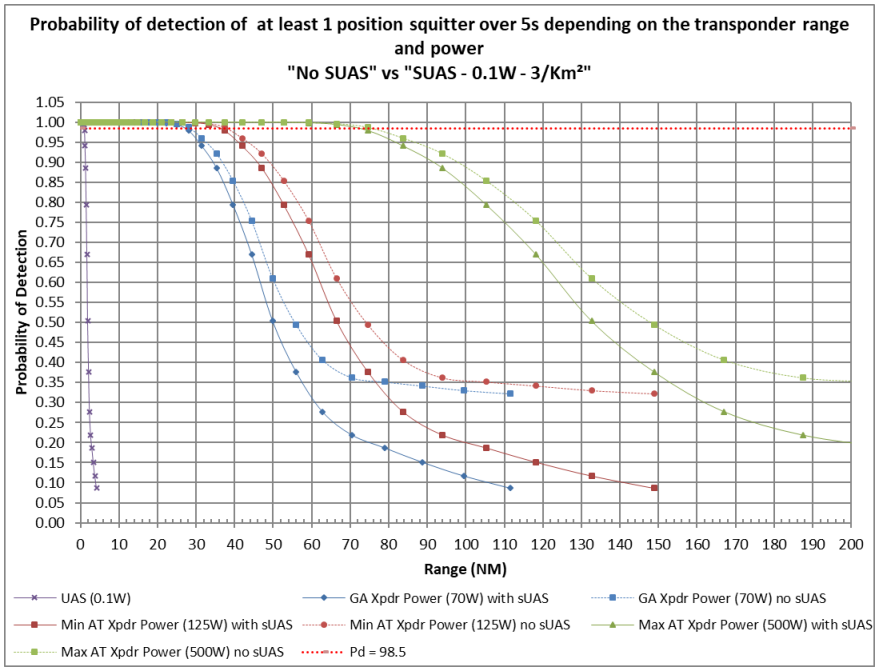
NO SUAS	**N/A**	**34.5**	**46**	**91.8**
0.5/Km²	3.6 (1W)	30.4 (11.88%)	40.6 (11.74%)	81 (11.76%)
1/Km²	3.3 (1W)	27.4 (20.58%)	36.6 (20.43%)	73 (20.48%)
3/Km²	2.4 (1W)	20.4 (40.87%)	27.2 (40.87%)	54.3 (40.85%)

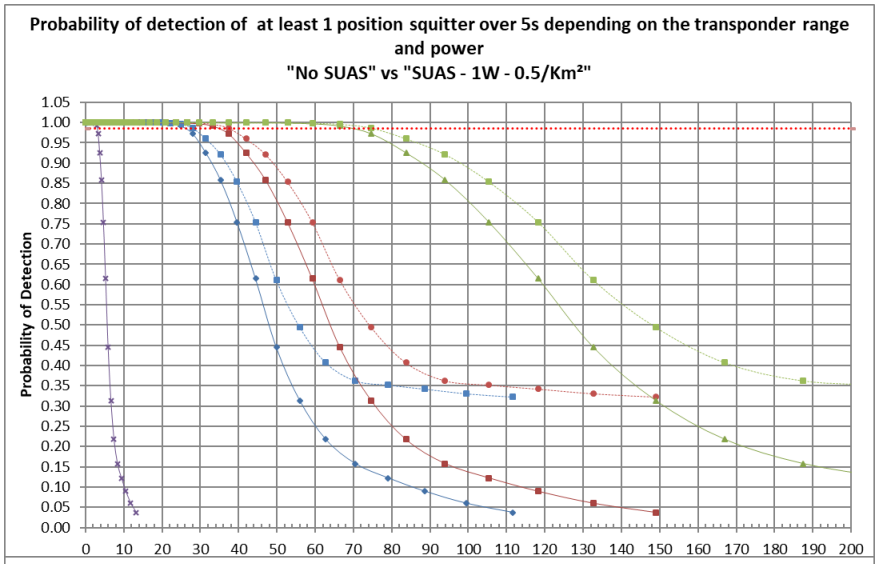
Probability of Update 5s – FRA 2016 – 0.1w

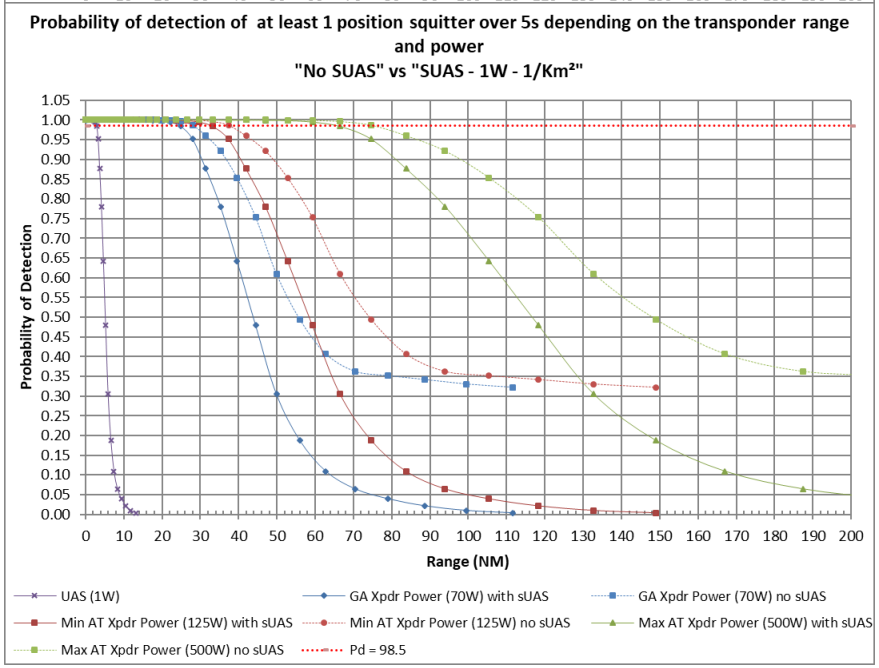




	Max detection range (in NM) PD of 1 position squitter in 5 second = 98.5%			
SUAS Scenario 0.1W	SUAS	GA Xpdr Power 46dBm - 70W	Min Air Transport Xpdr Power 51dBm - 125W	Max Air Transport Xpdr Power 57dBm - 500W
NO SUAS	**N/A**	**28.3**	**37.7**	**75.3**
0.5/Km²	1.1 (0.1W)	28.1 (0.71%)	37.5 (0.53%)	74.9 (0.53%)
1/Km²	1.1 (0.1W)	27.9 (1.41%)	37.2 (1.33%)	74.3 (1.33%)
3/Km²	1 (0.1W)	26.8 (5.30%)	35.8 (5.04%)	71.4 (5.18%)

Probability of Update 5s – FRA 2016 – 1w





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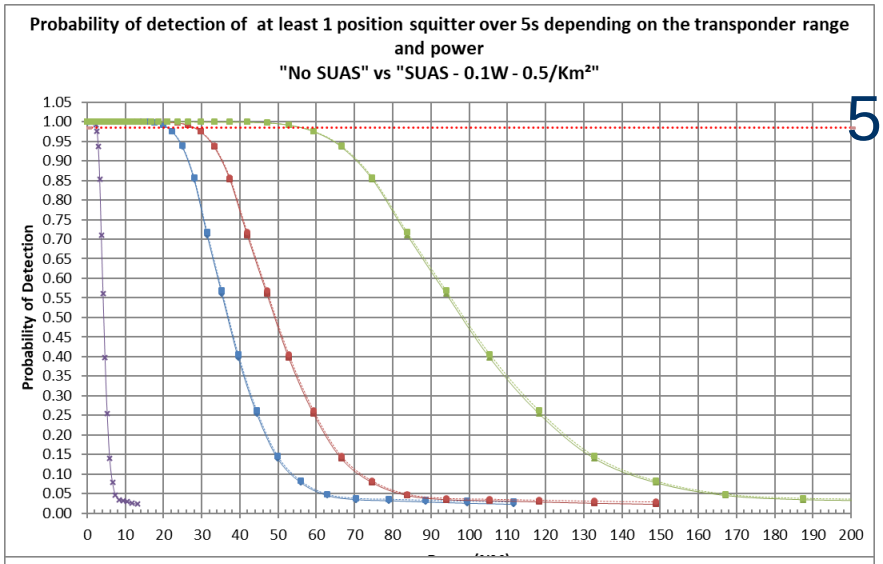
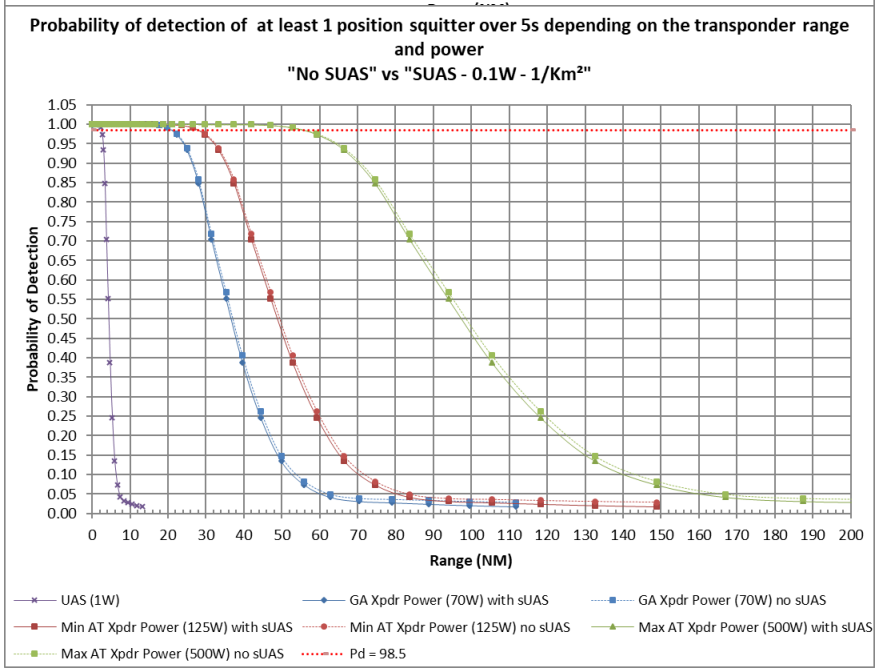
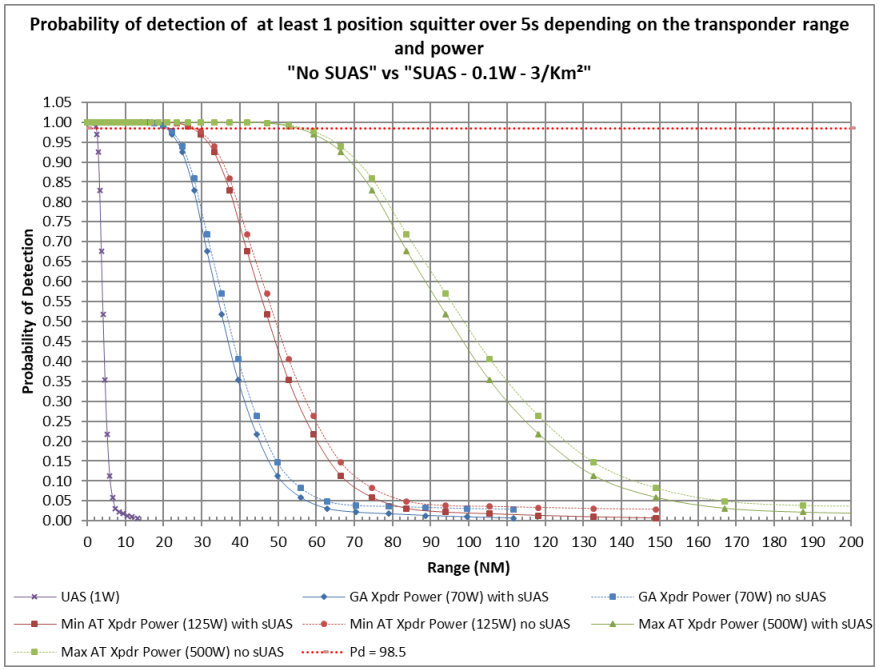
SUAS Scenario 1W	SUAS	GA Xpdr Power 46dBm - 70W	Min Air Transport Xpdr Power 51dBm - 125W	Max Air Transport Xpdr Power 57dBm - 500W
NO SUAS	**N/A**	**28.3**	**37.7**	**75.3**
0.5/Km²	3.1 (1W)	26.1 (7.77%)	34.8 (7.69%)	69.4 (7.84%)
1/Km²	2.9 (1W)	24.6 (13.07%)	32.9 (12.73%)	65.6 (12.88%)
3/Km²	2.4 (1W)	20 (29.33%)	26.7 (29.18%)	53.3 (29.22%)

Probability of Update 5s – FRA 2025 – 0.1w

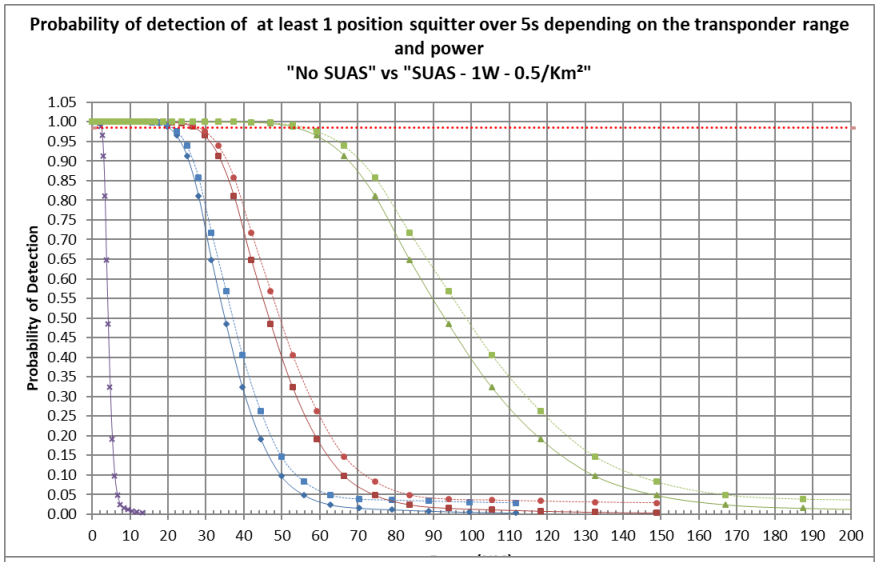


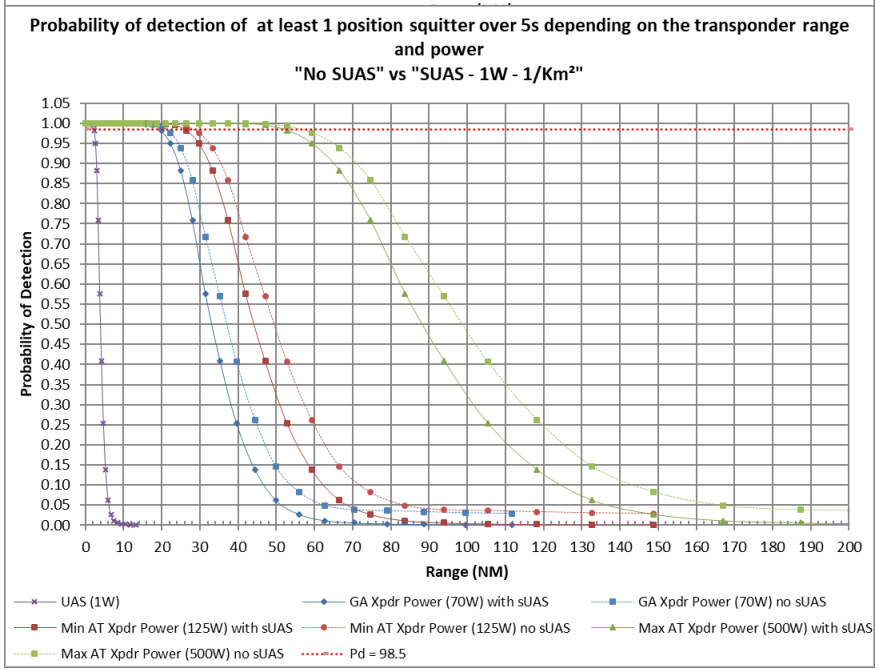




	Max detection range (in NM) PD of 1 position squitter in 5 second = 98.5%			
SUAS Scenario 0.1W	SUAS	GA Xpdr Power 46dBm - 70W	Min Air Transport Xpdr Power 51dBm - 125W	Max Air Transport Xpdr Power 57dBm - 500W
NO SUAS	**N/A**	**21**	**28**	**55.8**
0.5/Km²	0.8 (0.1W)	20.9 (0.48%)	27.8 (0.71%)	55.5 (0.54%)
1/Km²	0.8 (0.1W)	20.8 (0.95%)	27.7 (1.07%)	55.2 (1.08%)
3/Km²	0.8 (0.1W)	20.4 (2.86%)	27.3 (2.50%)	54.4 (2.51%)

Probability of Update 5s – FRA 2025 – 1w





	Max detection range (in NM) PD of 1 position squitter in 5 second = 98.5%			
SUAS Scenario 0.1W	SUAS	GA Xpdr Power 46dBm - 70W	Min Air Transport Xpdr Power 51dBm - 125W	Max Air Transport Xpdr Power 57dBm - 500W
NO SUAS	**N/A**	**21**	**28**	**55.8**
0.5/Km²	2.4 (1W)	20.2 (3.81%)	26.9 (3.93%)	53.6 (3.94%)
1/Km²	2.3 (1W)	19.3 (8.10%)	25.8 (7.86%)	51.4 (7.89%)
3/Km²				

Summary – Probability of Update on 5 and 8 sec

		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)				Max detection range (in NM) PD of 1 position squitter in 8 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	SUAS	GA Transponder Power 46dBm - 70W	Min Air Transport Transponder Power 51dBm - 125W	Max Air Transport Transponder Power 57dBm - 500W
CDG 2016	**NO SUAS**	N/A	34.5	46	91.8	N/A	40.8	54.4	108.5
	0.1W – 0.5/Km²	1.3 (0.1W)	34 (1.45%)	45.3 (1.52%)	90.4 (1.53%)	1.5 (0.1W)	40.2 (1.47%)	53.7 (1.29%)	107.1 (1.29%)
	0.1W – 1/Km²	1.3 (0.1W)	33.5 (2.90%)	44.6 (3.04%)	89 (3.05%)	1.5 (0.1W)	39.8 (2.45%)	53.1 (2.39%)	106 (2.30%)
	0.1W – 3/Km²	1.2 (0.1W)	32 (7.25%)	42.7 (7.17%)	85.1 (7.30%)	1.4 (0.1W)	37.6 (7.84%)	50.2 (7.72%)	100.1 (7.74%)
	1W – 0.5/Km²	3.6 (1W)	30.4 (11.88%)	40.6 (11.74%)	81 (11.76%)	4.3 (1W)	36.4 (10.78%)	48.5 (10.85%)	96.7 (10.88%)
	1W – 1/Km²	3.3 (1W)	27.4 (20.58%)	36.6 (20.43%)	73 (20.48%)	4 (1W)	33.5 (17.89%)	44.6 (18.01%)	89 (17.97%)
	1W – 3/Km²	2.4 (1W)	20.4 (40.87%)	27.2 (40.87%)	54.3 (40.85%)	3 (1W)	25.4 (37.75%)	33.8 (37.87%)	67.5 (37.79%)
FRA 2016	**NO SUAS**	N/A	28.3	37.7	75.3	N/A	34.6	46.1	92.1
	0.1W – 0.5/Km²	1.1 (0.1W)	28.1 (0.71%)	37.5 (0.53%)	74.9 (0.53%)	1.3 (0.1W)	34.1 (1.45%)	45.5 (1.30%)	90.7 (1.52%)
	0.1W – 1/Km²	1.1 (0.1W)	27.9 (1.41%)	37.2 (1.33%)	74.3 (1.33%)	1.3 (0.1W)	33.6 (2.89%)	44.8 (2.82%)	89.5 (2.82%)
	0.1W – 3/Km²	1 (0.1W)	26.8 (5.30%)	35.8 (5.04%)	71.4 (5.18%)	1.2 (0.1W)	32.2 (6.94%)	43 (6.72%)	85.8 (6.84%)
	1W – 0.5/Km²	3.1 (1W)	26.1 (7.77%)	34.8 (7.69%)	69.4 (7.84%)	3.7 (1W)	31.3 (9.54%)	41.7 (9.54%)	83.3 (9.55%)
	1W – 1/Km²	2.9 (1W)	24.6 (13.07%)	32.9 (12.73%)	65.6 (12.88%)	3.4 (1W)	28.9 (16.47%)	38.6 (16.27%)	77 (16.40%)
	1W – 3/Km²	2.4 (1W)	20 (29.33%)	26.7 (29.18%)	53.3 (29.22%)	2.8 (1W)	23.8 (31.21%)	31.8 (31.02%)	63.4 (31.16%)
FRA 2025	**NO SUAS**	N/A	21	28	55.8	N/A	25.3	33.8	67.4
	0.1W – 0.5/Km²	0.8 (0.1W)	20.9 (0.48%)	27.8 (0.71%)	55.5 (0.54%)	1 (0.1W)	25.2 (0.40%)	33.7 (0.30%)	67.2 (0.30%)
	0.1W – 1/Km²	0.8 (0.1W)	20.8 (0.95%)	27.7 (1.07%)	55.2 (1.08%)	1 (0.1W)	25.2 (0.40%)	33.6 (0.59%)	67 (0.59%)
	0.1W – 3/Km²	0.8 (0.1W)	20.4 (2.86%)	27.3 (2.50%)	54.4 (2.51%)	0.9 (0.1W)	24.8 (1.98%)	33 (2.37%)	65.9 (2.23%)
	1W – 0.5/Km²	2.4 (1W)	20.2 (3.81%)	26.9 (3.93%)	53.6 (3.94%)	2.9 (1W)	24.1 (4.74%)	32.2 (4.73%)	64.2 (4.75%)
	1W – 1/Km²	2.3 (1W)	19.3 (8.10%)	25.8 (7.86%)	51.4 (7.89%)	2.7 (1W)	23 (9.09%)	30.7 (9.17%)	61.3 (9.05%)
	1W – 3/Km²	Not run – see Section 7.7				Not run – see Section 7.7			

Conclusion

- The detection range of aircraft decreases when:
  - the ADS-B output power of SUAS increases
  - the density of SUAS increases.
- The environments with a higher number of aircraft (higher density of aircraft) less impacted by the ADS-B broadcasted by SUAS.
  - the detection range at CDG decreases more rapidly than at FRA with SUAS.
- The impact of **SUAS with ADS-B output power** limited to **0.1W** on the aircraft detection range would be acceptable.
  - Detection range reduced by less than 8% (CDG) compared to the environment without SUAS (could by more in an environment with very low density aircraft).
- The impact of **SUAS with ADS-B output power** set to **1W** on the aircraft detection range is more important.
  - Up to 41% (at CDG) of detection range reduction
  - A very low density of SUAS may remain acceptable (up to 12% at CDG)
- Impact should be further investigated for other scenarios including airborne 1090MHz receivers.