Impact of ADS-B rate on 1090MHz

Surveillance/MICA Workshop

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Study Purpose and Environment

- Investigate the impact of the increase of ADS-B squitter rate on Mode S aircraft detection by an 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)

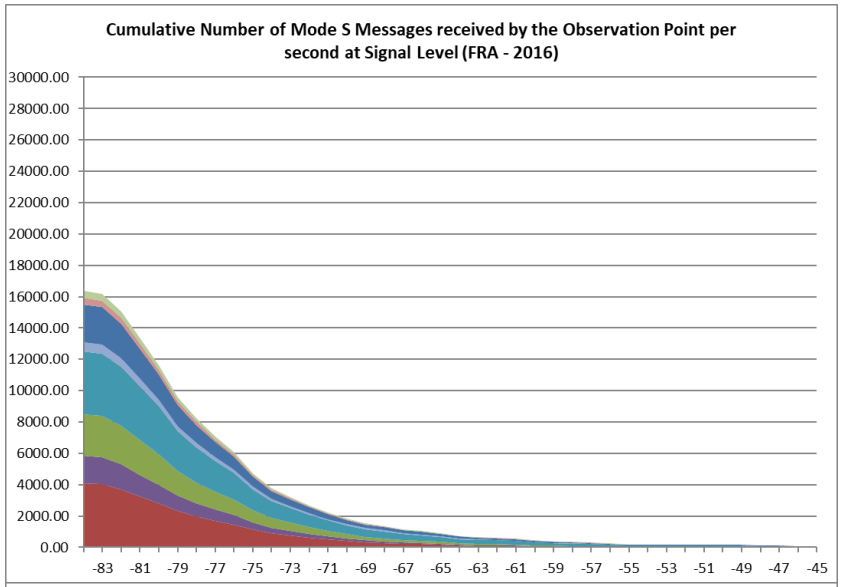
Study Hypothesis

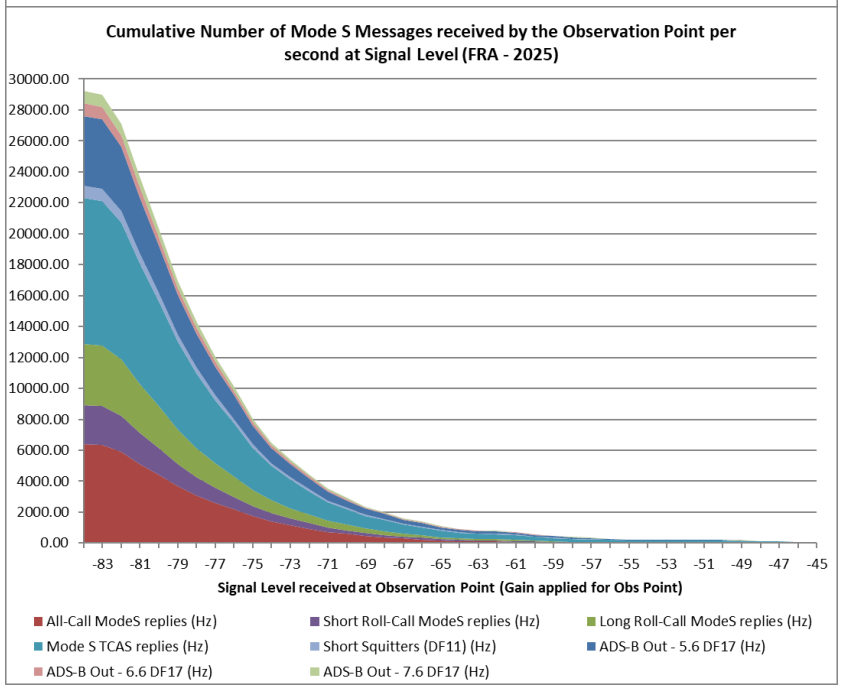
- Detection by omni-directional antenna at MTL = -84dBm with 7dB gain

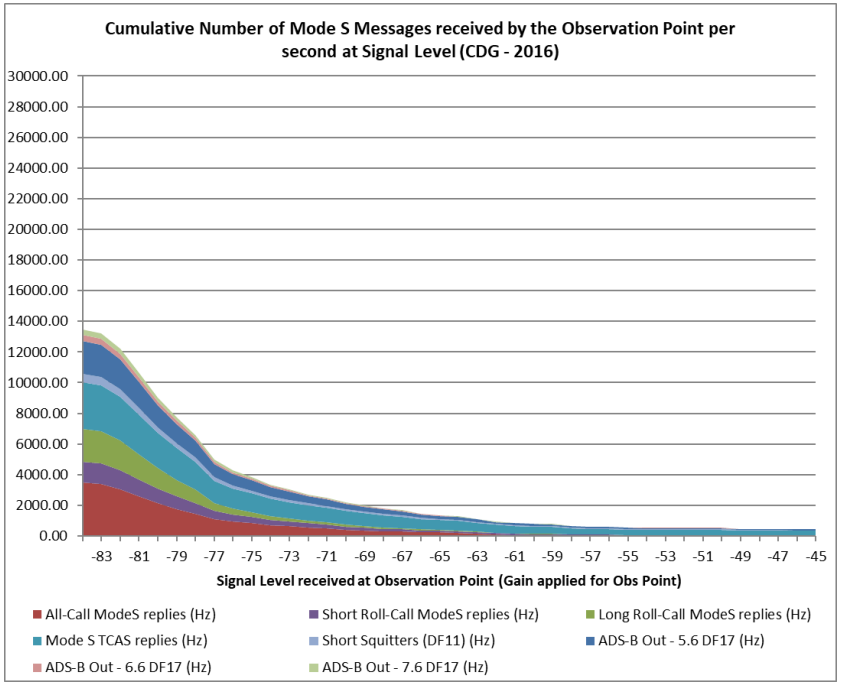
- The main variable of the simulation is the ADS-B squitter rate used by aircraft in the air.
- The following ADS-B squitter rate are compared:
  - 5.6 DF17 per second
  - 6.6 DF17 per second
  - 7.6 DF17 per second

- 2.2 DF17 per second for aircraft on the ground

Cumulative Mode S Message Rate





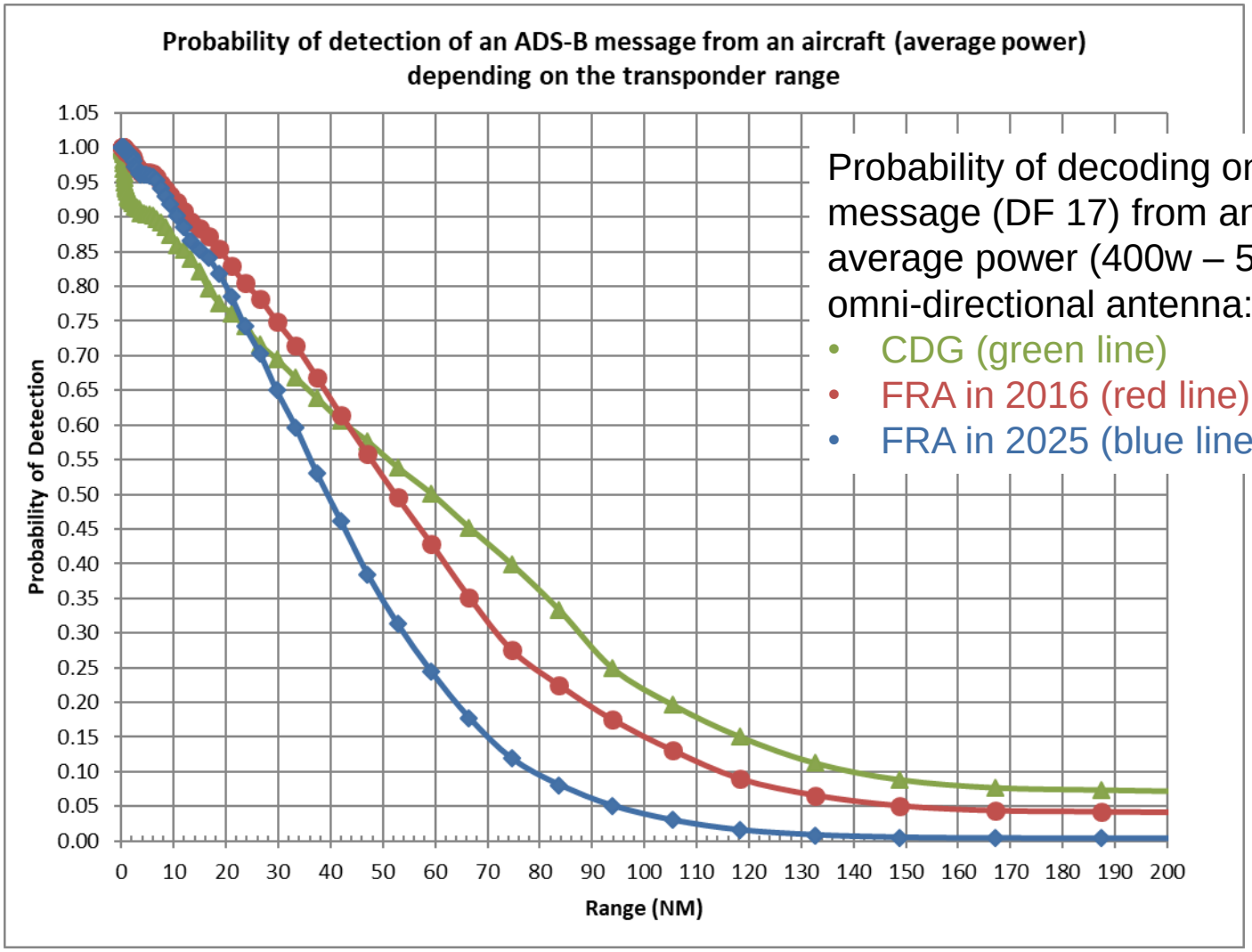


Decoding Probability of Garbled Messages

- 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

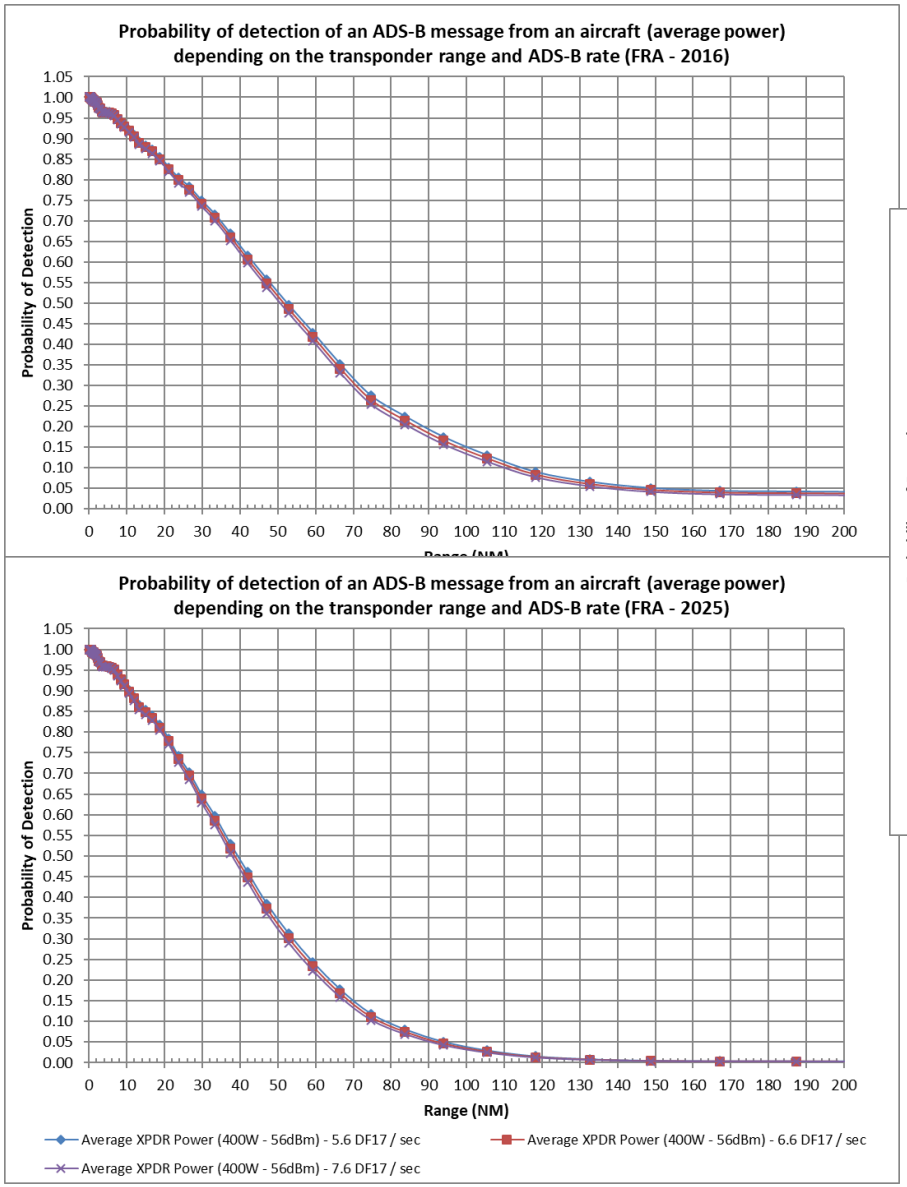
Probability of Decoding – 5.6 DF17 / sec

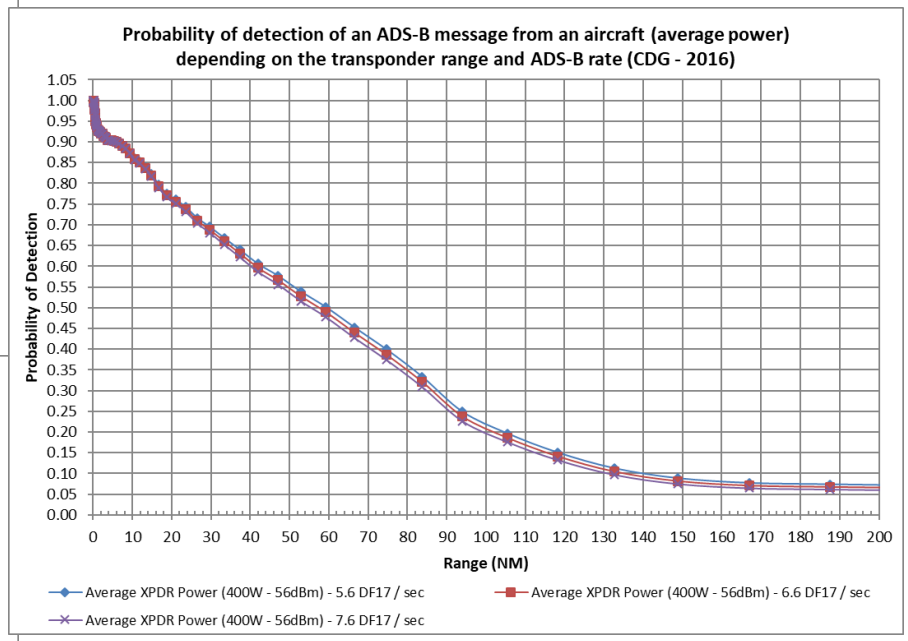


Probability of decoding one ADS-B message (DF 17) from an aircraft with average power (400w – 56dBm) by omni-directional antenna:

- 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
- ADS-B squitter rate

Probability of Decoding vs Probability of Update

Example at CDG

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

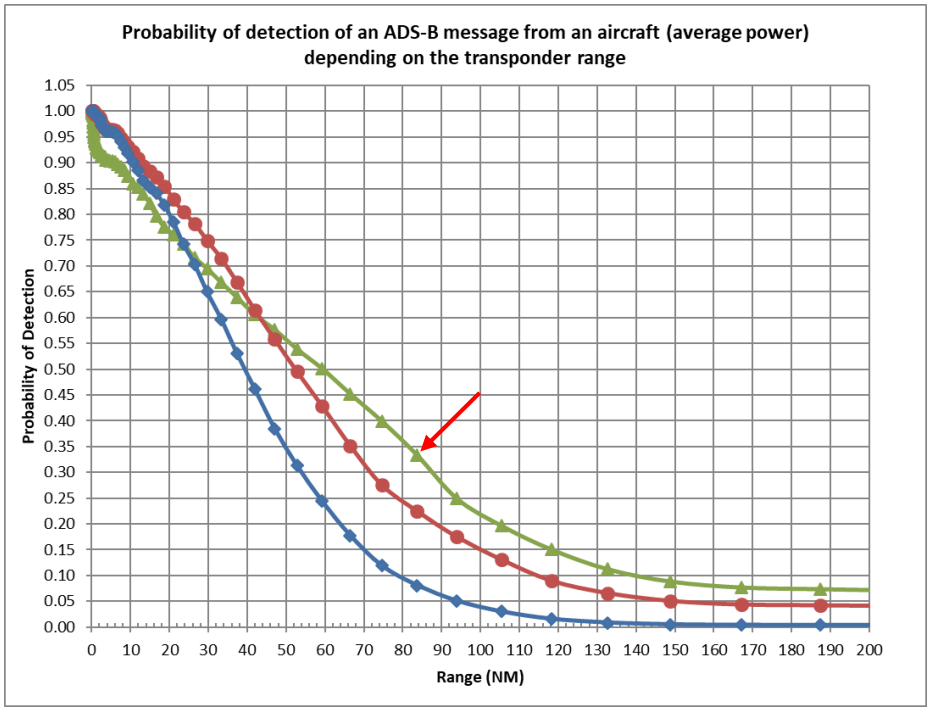
- 1 – ((1 – 0.3335) x (1- 0.3335)) = 0.5558

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

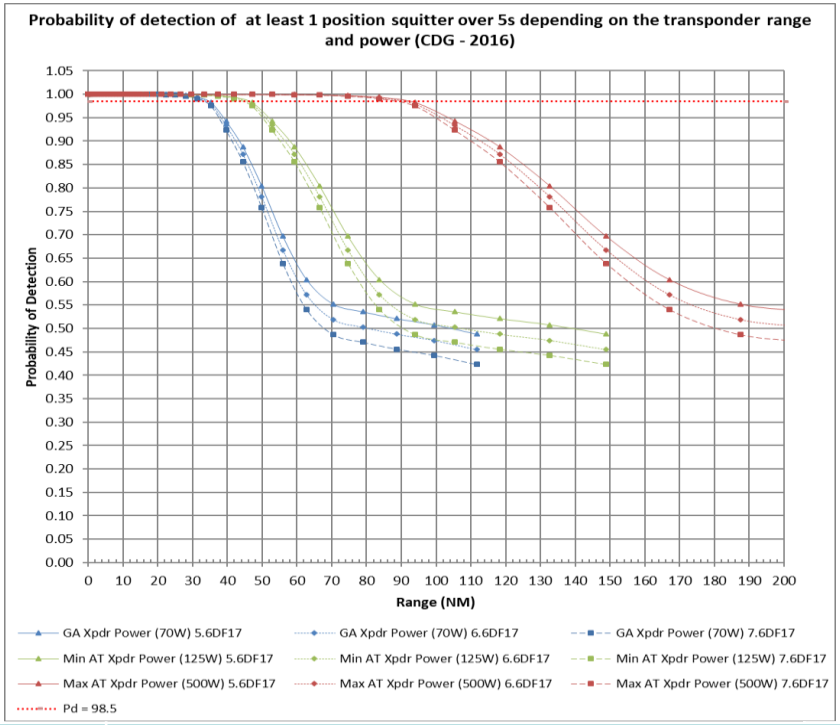
- 1 – 0.6665^10 = 0.9827

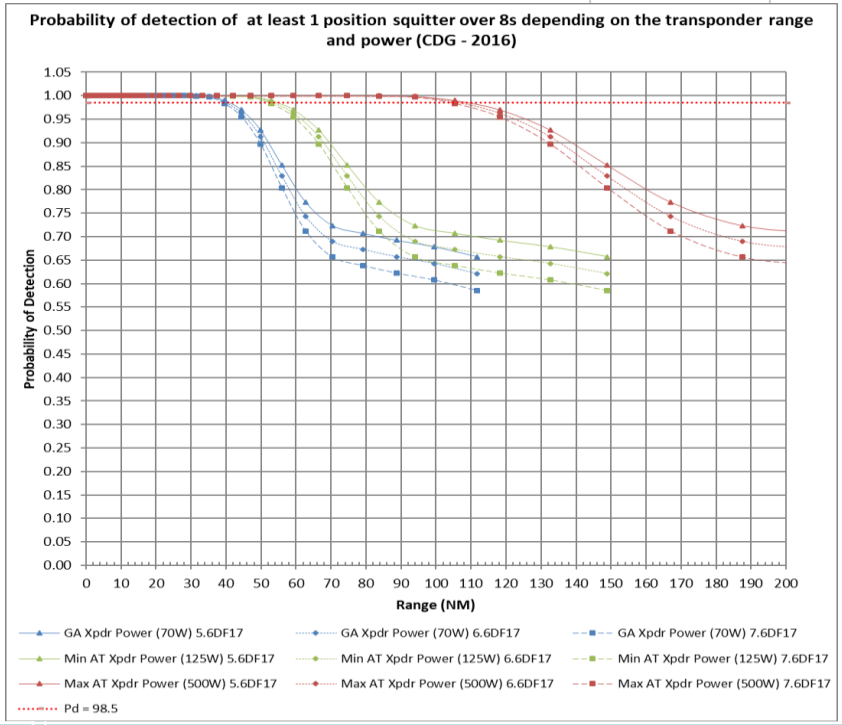
Probability to decode at least one position squitter per 8 second (probability of update on 8 sec)

- 1 – 0.6665^16 = 0.9985



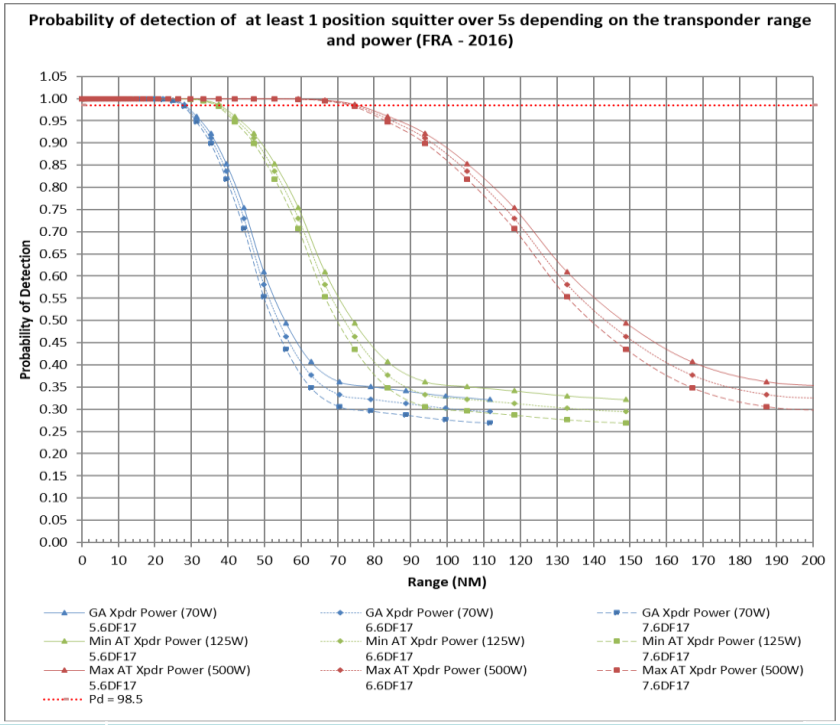
Probability of Update - CDG 2016

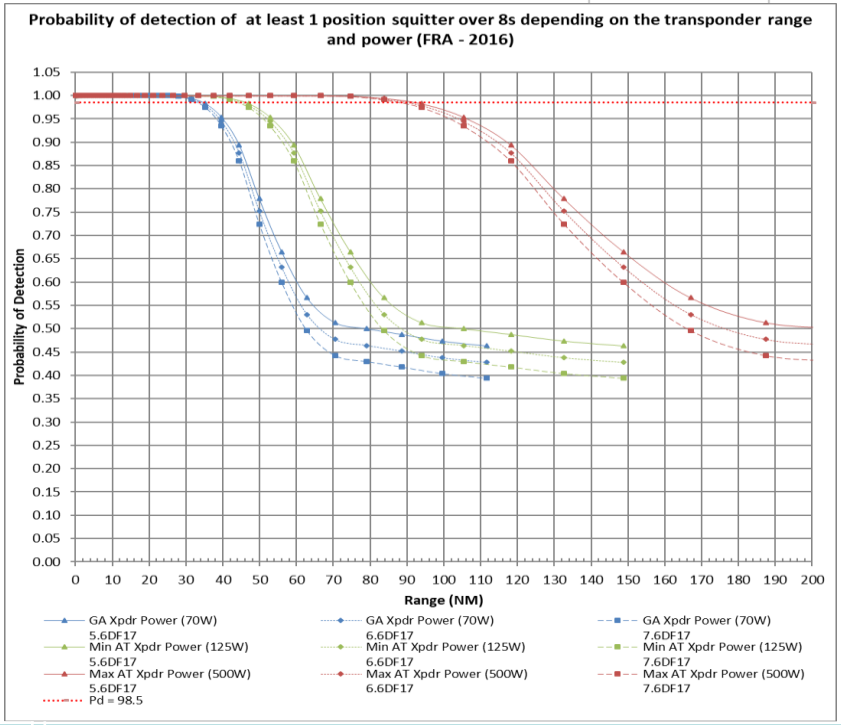




	Max detection range (in NM) PD of 1 position squitter in 5 second = 98.5%						Max detection range (in NM) PD of 1 position squitter in 8 second = 98.5%					
ADS-B Squitter Rate	General Aviation (46dBm – 70W)		Min Air Transport Transponder Power (51dBm – 125W)		Max Air Transport Transponder Power (57dBm – 500W)		General Aviation (46dBm – 70W)		Min Air Transport Transponder Power (51dBm – 125W)		Max Air Transport Transponder Power (57dBm – 500W)	
	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction
5.6 DF 17 / second	34.5	0%	46	0%	91.8	0%	40.8	0%	54.4	0%	108.5	0%
6.6 DF 17 / second	33.6	2.61%	44.8	2.61%	89.4	2.61%	40	1.96%	53.3	2.02%	106.4	1.94%
7.6 DF 17 / second	32.9	4.64%	43.9	4.57%	87.5	4.68%	39.1	4.17%	52.2	4.04%	104.2	3.96%

Probability of Update - FRA 2016





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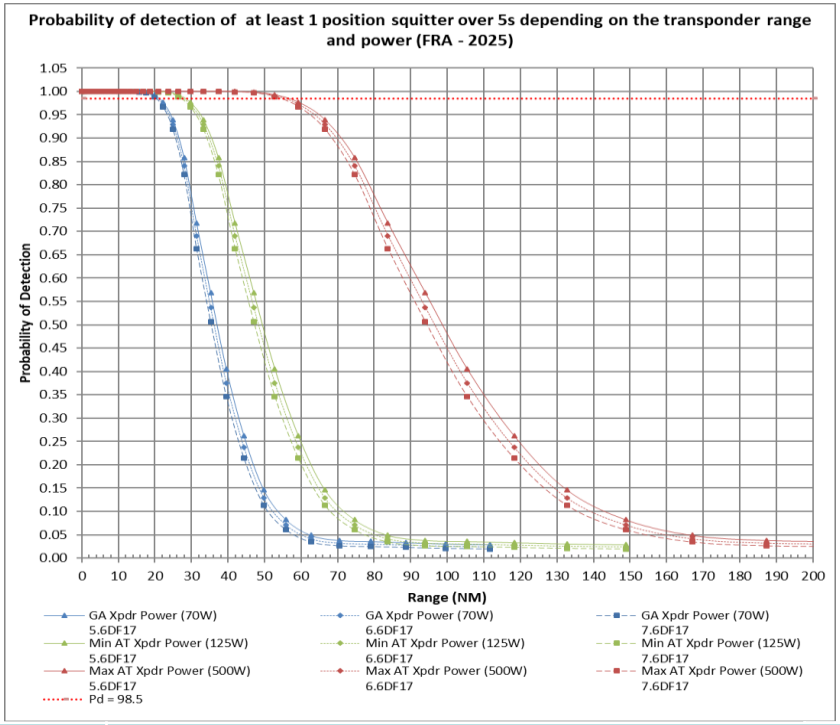
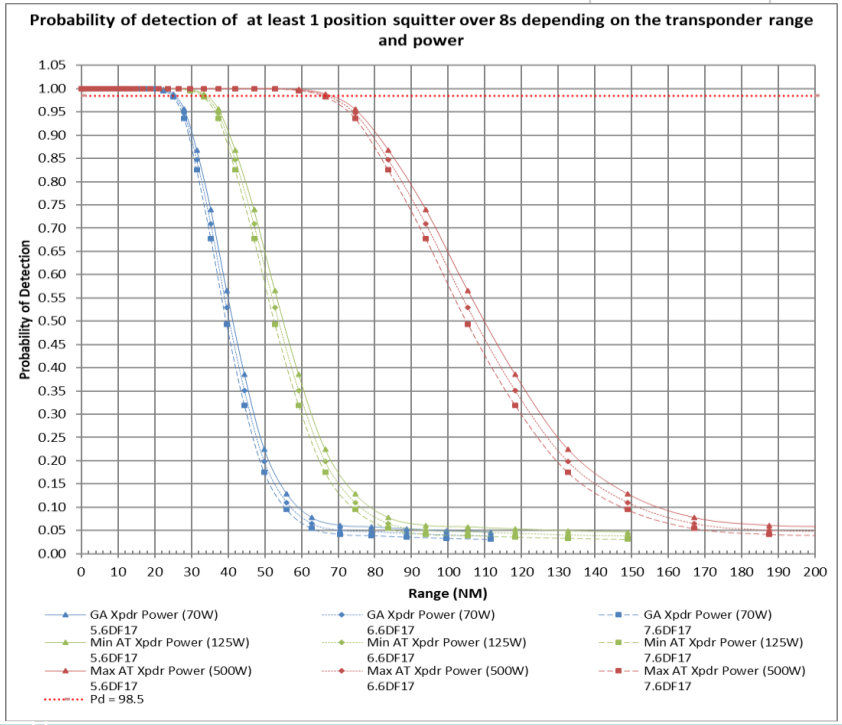
	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction
5.6 DF 17 / second	28.3	0%	37.7	0%	75.3	0%	34.6	0%	46.1	0%	92.1	0%
6.6 DF 17 / second	27.9	1.41%	37.2	1.33%	74.3	1.33%	33.6	2.89%	44.9	2.6%	89.5	2.82%
7.6 DF 17 / second	27.3	3.53%	36.4	3.45%	72.7	3.45%	32.9	4.91%	43.8	4.99%	87.4	5.1%

Probability of Update - FRA 2025





	Max detection range (in NM) PD of 1 position squitter in 5 second = 98.5%						Max detection range (in NM) PD of 1 position squitter in 8 second = 98.5%					
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	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction	Range (NM)	Range Reduction
5.6 DF 17 / second	21	0%	28	0%	55.8	0%	25.3	0%	33.8	0%	67.4	0%
6.6 DF 17 / second	20.6	1.9%	27.4	2.14%	54.7	1.97%	25	1.19%	33.4	1.18%	66.6	1.19%
7.6 DF 17 / second	20.2	3.81%	27	3.57%	53.9	3.41%	24.4	3.56%	32.5	3.85%	64.9	3.71%

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 5.6 DF17/sec)						Max detection range (in NM) PD of 1 position squitter in 8 second = 98.5% (Range Reduction in % compared to the scenario with 5.6 DF17/sec)					
	ADS-B Squitter Rate	General Aviation (46dBm – 70W)		Min Air Transport Transponder Power (51dBm – 125W)		Max Air Transport Transponder Power (51dBm – 125W)		General Aviation (46dBm – 70W)		Min Air Transport Transponder Power (51dBm – 125W)		Max Air Transport Transponder Power (51dBm – 125W)	
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	7.6 DF 17 / second	20.2	3.81%	27	3.57%	53.9	3.41%	24.4	3.56%	32.5	3.85%	64.9	3.71%

Conclusion

- The detection range of aircraft decreases when the ADS-B squitter rate increases.

- The impact of **ADS-B squitters with a rate of 6.6 DF17 / second and 7.6 DF17 / second** would be acceptable.
  - Detection range reduced by less than 5.1% when ADS-B rate is set to 7.6 DF17 / second compared to the environment with ADS-B rate set to 5.6 DF17 / second.

- Impact should be further investigated for other scenarios including airborne 1090MHz receivers.