DPMF Monitoring flights report 2017

This report is the 'monitoring flights report' as identified in the DPMF Report Catalogue. It provides measures of the airborne channel occupancy (metric A-1) and the airborne burst collision rate (metric A-2) for the recent data link monitoring flights undertaken by the DPMF as well as complementary information about channel usage.

1 Description of the flights

The data link monitoring flights undertaken by the NM since 2015 have followed the same flight path with a cruising altitude of FL360/FL370, departing from Amsterdam airport and following in a clockwise direction the course shown below in green before returning again to Amsterdam. The course and altitude were subject to minor operational changes during each flight, but essentially the route has been kept the same to allow comparisons to be made over time.

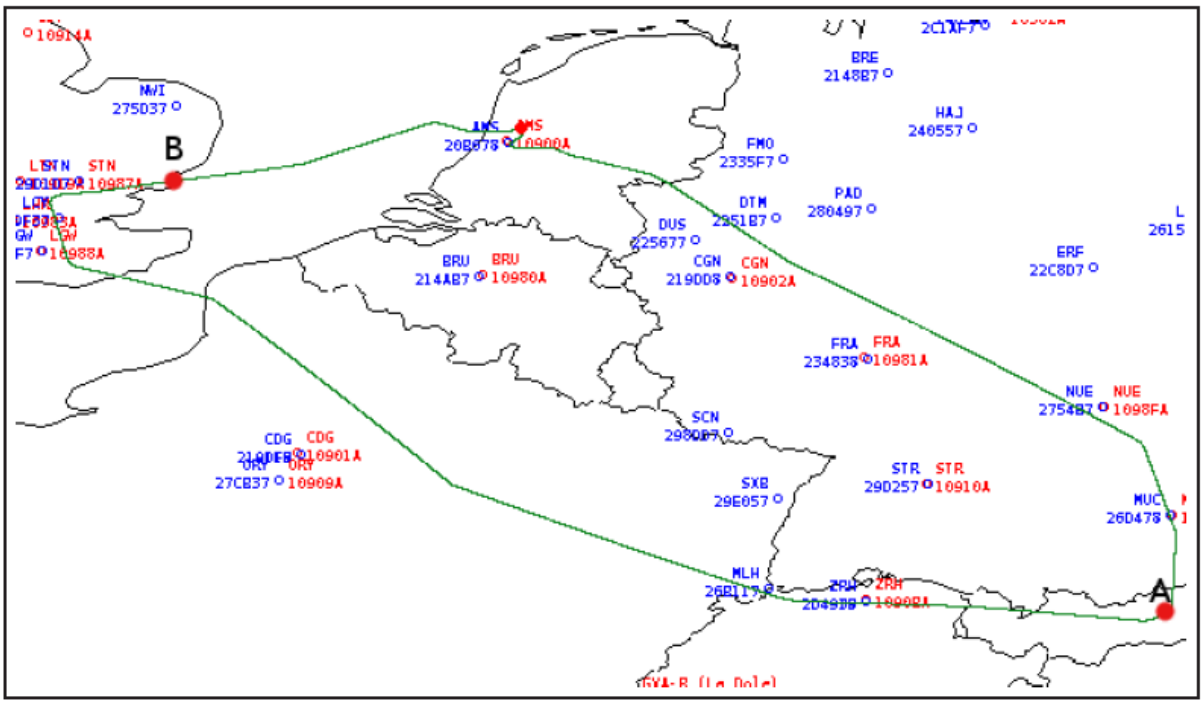

Figure 1: Flight Route

A Rhode and Schwarz EM100 receiver is used to acquire IQ (amplitude and phase) data over a bandwidth of 500Khz centred on centre of the VDL band (136.8375MHz). This data is then post-processed to extract the VDL frames, decode them where possible, and analyse collisions. Additional recordings are taken on the ground at different locations and SITA VGS logs have also been used to assist the analysis in some cases.

2 VDL Channel Use Summary

2.1 Interference Observed

Table 1 below summarises the usage of the VDL band as observed during the different data link monitoring flights. A green arrow indicates a correct usage of the channel and red indicates an incorrect usage of the channel.

Freq. (MHz)	Use (2017)	VDL2				Voice				Misc.			
		2015	2016	2017 04	2017 07	2015	2016	2017 04	2017 07	2015	2016	2017 04	2017 07
136.975	CSC	✓	✓	✓	✓	✓	✓	✓	✓				
136.950	-					✓	✓		✓				
136.925	VDL4												
136.900	-						✓		✓				
136.875	SITA Terminal	✓	✓	✓	✓								
136.850	-					✓					POA	POA	
136.825	ARINC Terminal					✓	✓	✓	✓				
136.800	-					✓							
136.775	SITA En-Route		✓	✓	✓								SC
136.750	-						✓		✓	POA			
136.725	ARINC En-Route		✓	✓	✓								
136.700	-						✓	✓					

Table 1 VDL Band Usage

Table 2 below shows a summary of the different types of interference observed on each flight[1].

	VDL Band (HH:MM:SS)			
	2015 August	2016 August	2017 April	2017 July
Modulated voice signals	00:02:58	00:21:04	00:01:42	00:01:54
RTTY-like signals (less than)	00:00:34	00:00:14	00:02:27	00:00:28
5-tones selcall	-	-	-	00:00:23
Industrial *noise-like*	00:34:56	00:12:59	00:04:32	00:10:36
Total	**00:38:53**	**00:34:17**	**00:08:41**	**00:13:21**

Table 2: Summary of interference observed

Voice communications continue to be observed on the VDL channels. As a result of work by the RAFT group City Jet were identified as a transmitter on 136.825MHz and City Jet reported that the use of this channel would cease in July 2017.

2.2 Origin of AVLC Frames Received

Table 3 below shows which proportion of the total number of bytes of data successfully received at the aircraft originated from each ACSP.

[1] More information on interference is provided in the CCRM report (Ref: C.C.R.M: 17/054/4/8CV)

Frequency	Assignation	2015 August		2016 August		2017 April		2017 July	
		SITA	ARINC	SITA	ARINC	SITA	ARINC	SITA	ARINC
136.975 MHz	CSC	56%	44%	62%	38%	57%	43%	55%	45%
136.875 MHz	SITA Terminal	80%	20%	96%	4%	100%	0%	100%	0%
136.825 MHz	ARINC Terminal	No VDL	No VDL	No VDL	No VDL	No VDL	No VDL	No VDL	No VDL
136.775 MHz	SITA En-Route	No VDL	No VDL	No VDL	No VDL	100%	0%	100%	0%
136.725 MHz	ARINC En-Route	No VDL	No VDL	0%	100%	0%	100%	0%	100%

Table 3: ACSP usage of channels

It can be seen that since at least April 2017 the channels are being used by the appropriate ACSP, and also that ARINC do not appear to have started using the 136.825MHz channel (intended as the ARINC terminal frequency).

2.3 Share of the total load on the CSC

Table 4 below shows how the total number of bytes received successfully by the different flights was shared between the CSC and the alternate frequencies. This shows the evolution of the distribution of traffic as multi-frequency is progressively deployed.

	2015 August		2016 August		2017 April		2017 July	
	CSC	Others	CSC	Others	CSC	Others	CSC	Others
ARINC	93%	7%	91%	9%	79%	22%	74%	26%
SITA	82%	18%	64%	36%	51%	49%	43%	57%

Table 4: Share of load between CSC and other frequencies

SITA have progressively been transferring load from the CSC on to their alternative frequencies and in the July 2017 nearly 60% of the SITA traffic was observed on the alternate frequencies. ARINC appear to be transferring traffic to the alternate frequencies at a slower pace.

2.4 Channel Load Evolution Index

Table 5 below shows the evolution in the total VDL Mode 2 traffic load. It is based on a summation of the lengths of all AVLC frames successfully received by each monitoring flight between points A and B across all VDL M2 channels. The total for August 2015 is taken as the reference for the index. It shows that the total traffic seen by the monitoring flight has doubled over the past two years, but of course this value is only based on a single flight each year so should be treated with some caution.

	2015 August	2016 August	2017 April	2017 July
Total load (ARINC + SITA)	1	1.24	0.91	1.98
CSC	0.82	0.86	0.55	1.03
Others	0.18	0.38	0.36	0.95
ARINC	0.43	0.43	0.33	0.67
CSC	0.40	0.38	0.25	0.47
Others	0.03	0.05	0.08	0.20
SITA	0.57	0.81	0.58	1.31
CSC	0.43	0.48	0.30	0.53
Others	0.14	0.33	0.28	0.78

Table 5: Channel Load Evolution Index

It can be seen that so far, although the deployment of multi-frequency is absorbing a large proportion of the increasing traffic, the load on the CSC is continuing to increase; there has been nearly a 100% increase in total traffic between August 2015 and July 2017 and although the alternate frequencies have taken a lot of that additional load, there is an increase of approximately 25% of the CSC loading.

It is important to note that this table is measuring the traffic successfully decoded, not the total load on the channel. It is interesting to note that in July 2017 over both service providers, the ratio of data successfully received on the CSC and the other channels combined is approximately 1:1 (in fact 1.03:0.98 see above), whereas the ratio of the channel occupancy between the CSC and the other frequencies combined is almost 2:1 (CSC mean occupancy was 32.1% and the sum of the means on the other channels is 16.8% - see Table 6). This illustrates the inefficiencies introduced when the collision rate becomes too high; the collision rate on the CSC was approximately 50% in July 2017 meaning that on average one frame in two on the CSC collided and needed to be re-sent, whereas on the other channels the collision rate is much lower (7.5%-16.26% see Table 7).

3 Channel Occupancy Statistics

Table 6 below shows various statistics for channel occupancy for each flight when the aircraft was above FL285, using a one-second integration period. The shape of the distribution of these delays is not a typical normal (Gaussian) distribution, so the mean, median, mode as well as the 5th percentile and 95th percentile values are given in order to characterise the distribution.

Frequency Assignment		2015 August	2016 August	2017 April	2017 July
136.975MHz CSC	Mean	22.53%	28.80%	19.01%	32.10%
	Mode	19.57%	19.95%	13.86%	28.23%
	P5	7.80%	10.55%	5.91%	15.74%
	Median	**20.95%**	**26.37%**	**17.34%**	**31.05%**
	P95	42.60%	53.80%	37.96%	51.86%
136.875MHz	Mean	2.26%	6.17%	5.36%	8.85%

Frequency		2015	2016	2017	
SITA Terminal	Mode	0.00%	0.00%	0.00%	2.80%
	P5	0.00%	0.00%	0.00%	0.66%
	Median	**0.64%**	**3.72%**	**3.00%**	**6.58%**
	P95	9.73%	23.01%	20.17%	26.13%
136.825MHz ARINC Terminal[1]	Mean		1.14%	0.39%	0.06%
	Mode		0.00%	0.00%	0.00%
	P5		0.00%	0.00%	0.00%
	Median		**0.00%**	**0.00%**	**0.00%**
	P95		0.00%	0.00%	0.00%
136.775MHz SITA Enroute	Mean		0.41%	1.48%	5.40%
	Mode		0.00%	0.00%	0.00%
	P5		0.00%	0.00%	0.00%
	Median		**0.00%**	**0.07%**	**3.51%**
	P95		0.00%	6.02%	17.99%
136.725MHz ARINC Enroute	Mean		0.56%	1.24%	2.53%
	Mode		0.00%	0.00%	0.00%
	P5		0.00%	0.00%	0.00%
	Median		**0.00%**	**0.00%**	**1.22%**
	P95		2.49%	6.87%	10.13%

Table 6: Occupancy above FL285 (-90dBm)

Notes: 1: There was no VDL traffic observed on this frequency, so the channel occupancy is some form of interference (e.g. voice).

The absolute figures given for the occupancy of the terminal frequencies are of questionable value since these figures are being measured when the aircraft is at considerable altitude and so does not represent the channel occupancy experienced by aircraft using the terminal frequency at the relevant airport. However the trend of these values does give an indication of the increasing usage of the SITA terminal channel and the apparent non-use of the ARINC terminal channel.

3.1 Detailed Channel Occupancy Graphs

The graphs below show the channel occupancy as observed from the aircraft for the different flight using a integration period of 60 seconds.

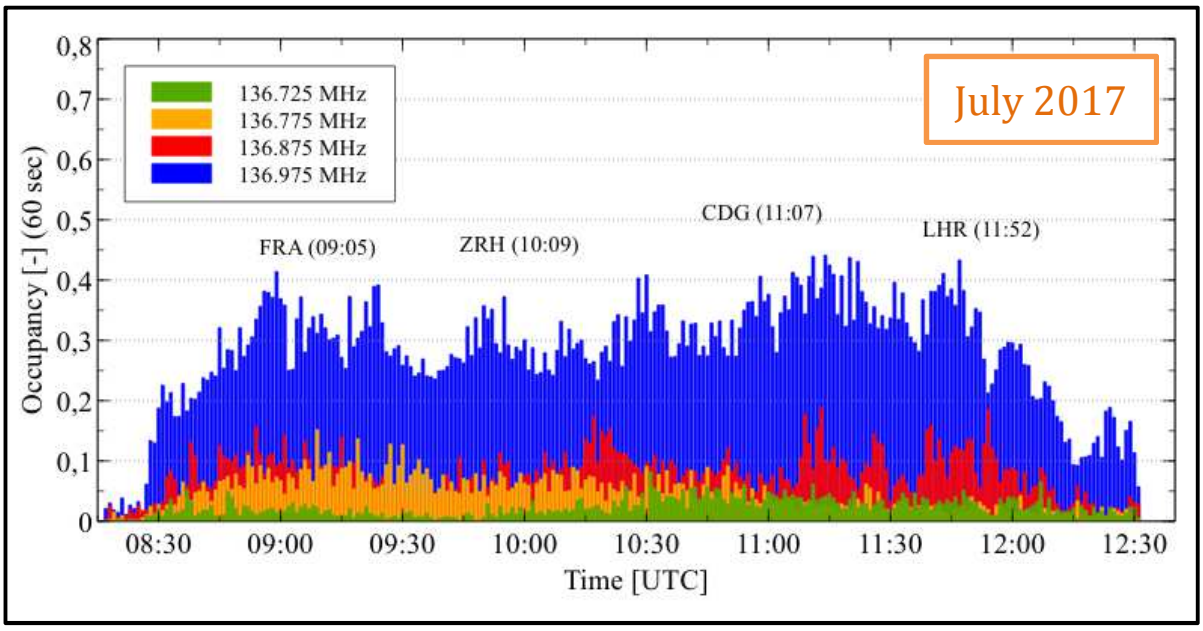

Figure 2: July 2017 Flight channel occupancy observed at aircraft

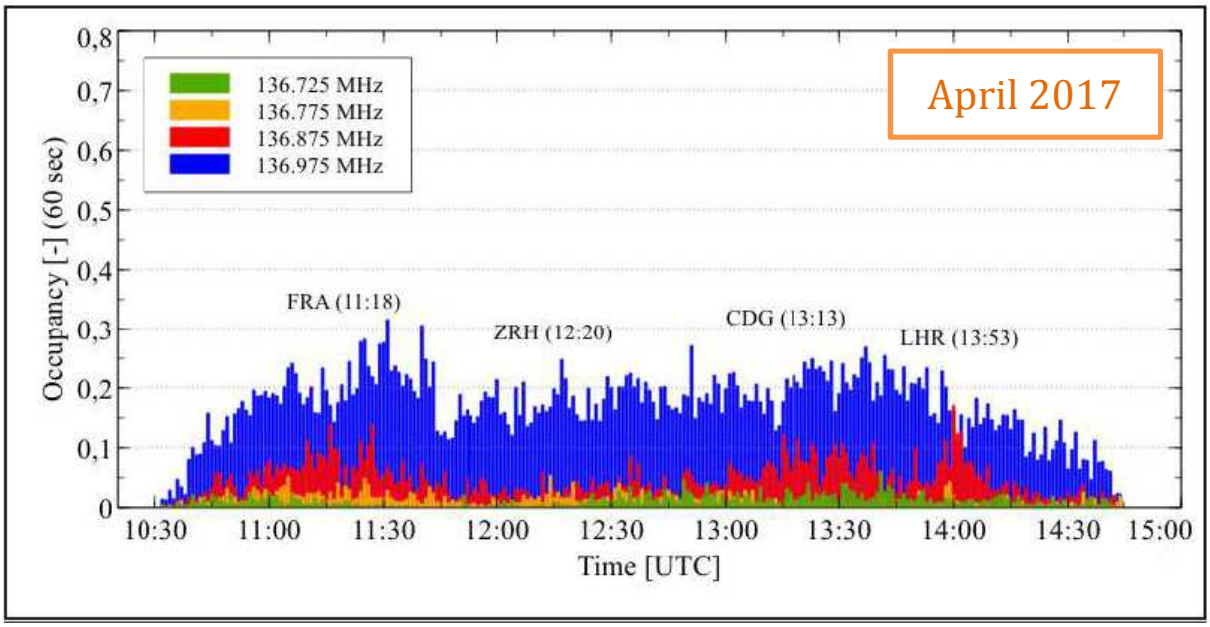

Figure 3: April 2017Flight Channel occupancy observed at aircraft

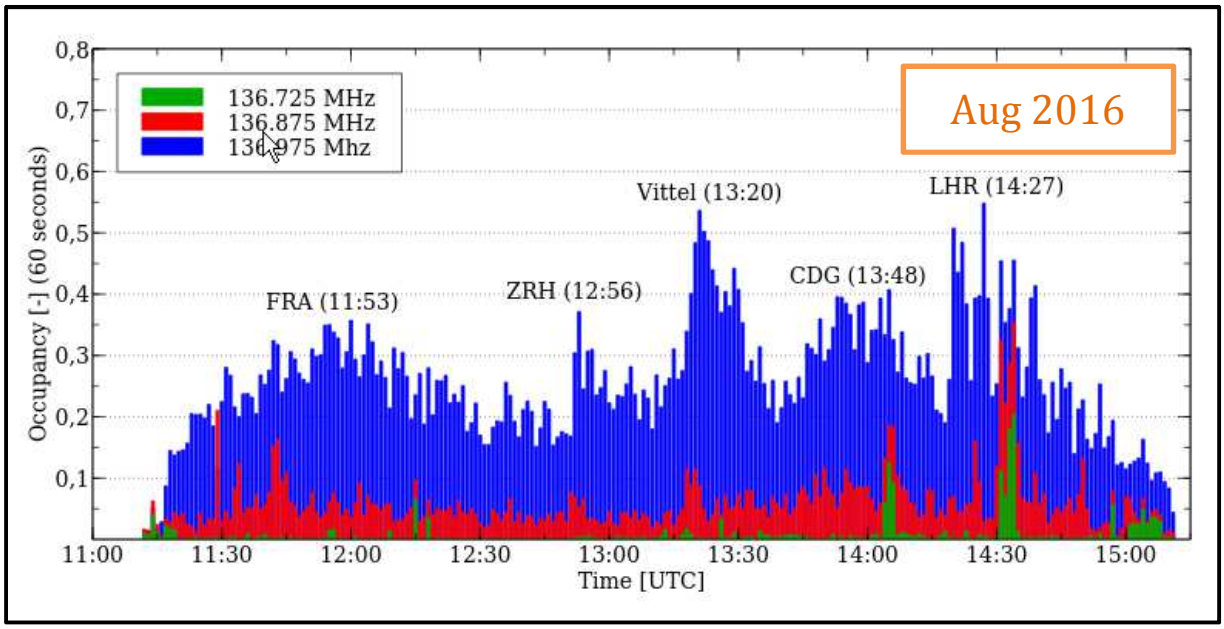

Figure 4: August 2016 Flight Channel occupancy observed at aircraft

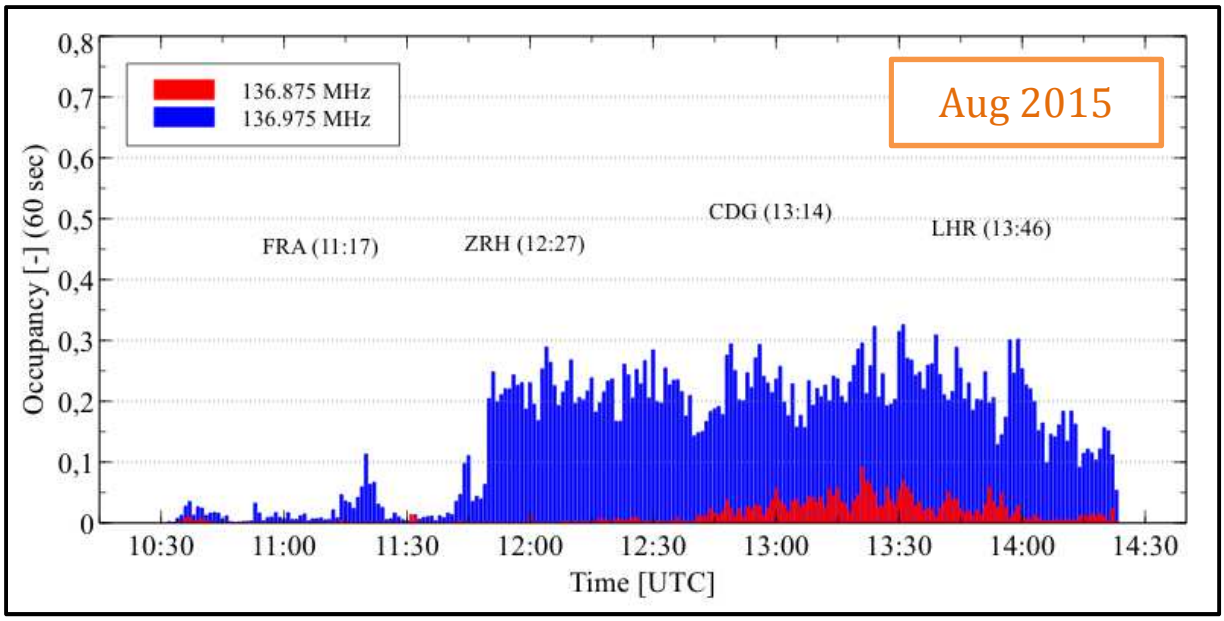

Figure 5: August 2015 Flight channel occupancy observed at aircraft

The August 2015 flight suffered from a bad connection which attenuated the signal recorded by the receiver until the problem was corrected in flight. This is why in Figure 5 the first 90 minutes of the flight show very low occupancy figures and the reason why certain metrics were only calculated between points A and B of the flight.

4 Airborne Collision Rate

Table 7 below shows the rate of burst collisions (metric A-2) observed on each flight using a set of 120 one second samples of the on-board recordings between points A and B as shown in Figure 1 above.

Frequency	Assignation	2015 August	2016 August	2017 April	2017 July
136.975 MHz	CSC	47.85%	42.57%	36.71%	50.28%
136.875 MHz	SITA terminal	-	16.31%	17.29%	16.26%
136.825 MHz	ARINC Terminal	-	-	-	-
136.775 MHz	SITA En-Route	-	-	TBD	7.52%
136.725 MHz	ARINC En-Route	-	0.00%	6.12%	9.92%

Table 7: Rate of burst collisions

There has been an increase in the collision rate as the traffic increases, although the increase on the CSC is modest given the approximately 25% increase in load between Aug 2015 and July 2017. One plausible explanation of this would be if there were fewer hidden transmitters on the CSC (due to more aircraft using the terminal frequency) in July 2017 than in Aug 2015, thereby causing relatively fewer collisions. However we have no data to support this, indeed the detailed analysis of the flight showed that over the flight as a whole there were more aircraft on the ground transmitting on the CSC in 2017 than there were in 2015.

4.1 Relationship between Channel Occupancy and Collision Rate

The graph in Figure 6 plots burst collision rate against channel occupancy of the CSC for the data link monitoring flights from August 2015, August 2016, April 2017 and July 2017.

As channel occupancy increases, the risk of burst collisions would also be expected to increase, and the data collected in Aug '16 and beyond does indeed exhibit a consistent trend between these parameters. However, the same measurements in Aug '15 do not conform to that trend, and show a substantially higher collision rate given the level of channel occupancy.

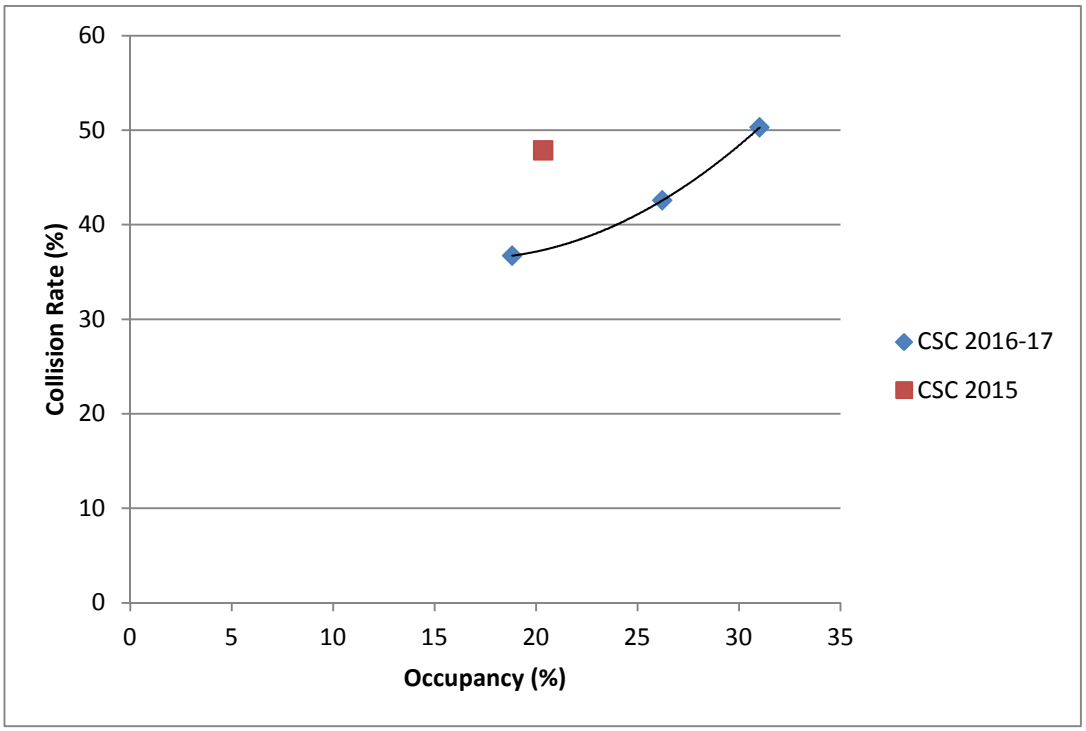

Figure 6: Collision Rate v Channel Occupancy

In the period between the flight trials in Aug '15 and Aug '16, SITA expanded use of the VDL M2 terminal frequency, and it appears likely that the reduction in the risk of burst collisions in Aug '16 and beyond is because of this. Following introduction of the terminal frequency, certain aircraft (with the appropriate avionics) were transferred away from the CSC to the terminal frequency, while on the airport surface, by means of the FSL protocol. Transmissions from grounded aircraft have been considered to be particularly disruptive to the VDL environment because these aircraft are hidden (due to their limited radio horizon) from other VGSs and are thus more likely to interfere with them than is the case for aircraft in the air. Accordingly, it has been hypothesised that a reduction in the risk of burst collisions should be expected from use of the terminal frequency above and beyond what would be expected purely from relief of load on the CSC.

This data also raises a question as to whether a further improvement in CSC performance could be achieved by more extensive transfer of aircraft to the terminal frequency than occurs at present.

5 Summary and Recommendations

The July 2017 flight is the fourth data link monitoring flight following the same flight profile across core Europe. Although these four flights constitute a very small sample and so need to be treated with some caution, they do provide a series of snapshots on the likely underlying trend of the network performance. Of the four flights, three have been undertaken around the peak of the summer (August 11th 2015, August 11th 2016 and July 27th 2017) and one has been undertaken around Easter (April 12th 2017). Due to the difference in the number of flights between April and July/August when considering the trend it is necessary to consider the summer series of flights separately from the April flight.

Looking at the series of summer flights from 2015, 2016 and 2017 the following observations and conclusions can be drawn:

- The amount of data being exchanged over VDL Mode 2 has doubled in the past two years.

- Multi-frequency deployment is mitigating the increased load on the CSC but so far has not succeeded in reducing the load on the CSC below the 2015 level. The median channel utilisation of the CSC was 20.95% in 2015 and 31.05% in 2017.

- The alternate frequencies are still being used much less than the CSC, so there is significant further opportunity to reduce the load on the CSC.

- SITA are putting a much higher proportion of their traffic on the alternative frequencies (i.e. non – CSC) than ARINC (57% versus 26% in July 2017), however the CSC usage is fairly evenly split between SITA and ARINC (55% SITA, 45% ARINC in July 2017).

- ARINC do not appear to be using the terminal frequency (136.825MHz).

These conclusions support the following recommendation:

1) ACSPs should continue to move traffic from the CSC to the alternate frequencies as quickly as possible to reduce the load on the CSC.

2) The ARINC terminal frequency should be deployed to reduce the number of aircraft on the ground using the CSC and acting as hidden transmitters.