NETWORK
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DPMF VDL2 MONITORING FLIGHT REPORT

April 2019 DPMF flight

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Abstract			
This document reports on the 7th VDL monitoring flight performed on 16.05.2019.			
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Edition History

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1   Summary

Twice a year, the DPMF conducts VDL monitoring flights in order to monitor the performance of the European Data Link Services (DLS) as seen from an aircraft perspective.

This report highlights the multi-frequency deployment and the rise of the observed traffic: The key points are listed below.

1. 67% of the observed traffic volume is now taking place on the alternate frequencies.

2. An increase of 12% of the traffic volume is observed between May 2018 and April 2019.

3. The traffic volume on the CSC is split 73% ARINC and 27% SITA.

4. The traffic on the CSC is continuously decreasing since July 2017.

5. 78% of the aircrafts on SITA's network are observed on its alternates frequencies while 56% for ARINC.

6. AOA represent 60% of the global traffic volume.

7. The median traffic rate increased by 15.7% between May 2018 and April 2019.

8. Voice communication are still heard on VDL2 frequencies

2   Introduction

The purpose of this document is to report some data link performance metrics, as defined in the DPMF report catalogue [5], from the last monitoring flight campaign that took place on April 16th, 2019 above core Europe. It also presents the evolution and trends of the measured parameters from the previous flights (since August 2015) as well as dedicated analyses.

As the monitoring flights are intended to analyse VHF Data Link at the airborne side, some effort has been made, when needed, to distinguish between airborne traffic (E-R) and ground traffic (Terminal) which is expected to be different in nature. However, except where stated otherwise, the traffic values presented in this report take into account all monitored frequencies as they are part of the monitoring flight results.

Since 2017, frequency assignments have been set according to AIR and GND categories (see ICAO Doc11 [7]). The designation of the frequencies in this report is then based on these two categories[1] The terminology "alternate" frequency used in this document refers to any frequency other than the CSC. For SITA, 136.875 MHz is assigned for GND and 136.775 MHz for AIR. For ARINC[2], 136.825 is assigned for AIR and 136.725 for GND.

Finally, we remind the reader that the traffic volume expressed in this report are measured on the RF channels as seen by the monitoring aircraft taking into account all the possible retransmissions observed as these are part of the real and observed traffic.

2.1   Outline of the report

Chapter 2 covers the measurement setup and the method of analysis.

Chapter 3 presents the results of the last monitoring flight together with the previous ones.

> *Remark: The metrics defined in [5] are highlighted in bold with the performance metric identification number between brackets.*

The **airborne channel occupancy (A-1)** is used as a simple estimator of the traffic load on the different channels. It is computed by dividing the number of samples whose level is above a certain threshold over the total number of samples observed during a time period. This report provides a mean airborne channel occupancy, and also an airborne channel occupancy statistic based on one second integrated values. The latter is intended to have comparable values to what the VDRs are supposed to provide.

The **airborne burst collision rate (A-2)** is an estimation of the number of collisions observed at FL370. It is computed by dividing the number of bursts

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[1] The denomination "mixed" frequency to denote a "mixed GND-AIR" frequency is not used as it is not compliant with the current ICAO Doc11 frequency plan.

[2] At the time of writing, ARINC is using its GND frequency (136.725 MHz) for both AIR and GND. The deployment of the AIR frequency is planned for 2019.

identified in a collision over the total number of bursts observed during a time period. It is used as an indicator to the correct behaviour of the radio channels. To achieve maximum throughput, the number of collisions needs to be minimal.

The **channel load (KPI_PHY_01)** is used to measure the evolution of traffic. It is defined as the sum of the AVLC frame size (in kB) by periods. It is also expressed in this report as a traffic rate in kbits/s computed as an average per second over periods of 60 seconds. The median and the 95th percentile values over the whole flight are presented. These values are also computed in function of the type of traffic (AOA, ATN or AVLC protocol related) referring to **KPI_PHY_02**.

This report also provides the distribution of traffic between the CSC and the alternate frequencies, and is used to monitor the traffic offload of the CSC in the scope of the multi-frequency deployment.

Interference reporting is presented for each type of observed interference in term of their total duration.

Chapter 4 covers discussion on the metric results.

Finally, **chapter 5** gives the conclusions and addresses recommendations.

3 Measurement setup and method of analysis

Measurements were performed using NLR[3]'s Cessna Citation II flying across Europe at FL370. The setup can be found in the annex 1.

Figure 3-1 : Typical flight route.

The analysis is performed using dedicated software tools.

IF-PAN (spectrum) data are converted into "spectrum tiles" to display the recorded spectrum in order to perform interference analysis. It is also used to list all the voice transmissions generated by the aircraft and overloading the receiver – the latter events being excluded from the following analysis.

The recorded IQ data (500 kHz) is first channelized to the desired 25 kHz channels and saved into separate IQ files.

Each channel is then processed to detect and demodulate bursts. Demodulated AVLC frames are saved into text files in a hexadecimal format with additional RF information (time-stamp, level, duration).

Airborne channel occupancy and other RF statistics (levels distribution) are also processed channel by channel and the results saved in text files.

AVLC frame analysis is performed for each generated channel log file providing with various statistics depending the ACSPs, AVLC frame types, time-stamps or plane location. Only correctly demodulated frames are used for the analysis.

Channelized IQ data (25 kHz) is also used to visually count the burst collisions over a set of 120 one-second data using a dedicated GUI tool. The latter is also capable of performing burst demodulation of a selected burst when required.

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[3] Nationaal Lucht-en Ruimtevaarlaboratorium (NL).

When needed IQ data is also used to demodulate other type of signals (i.e. voice, ACARS (POA))

4   Results

4.1   Airborne channel occupancy

Occupancy measurements are computed over channelized IQ data using 64 kSamples/s.

As occupancy values depends on the level threshold used, level density function graphs are provided for each frequency in the annex 3. In the following sections a -90 dBm threshold at the antenna is considered ("*idle to busy*" threshold defined in ICAO annex 10 [6]).

4.1.1   Average occupancy

The following tables summarizes the mean occupancy measured above FL285 since 2015. Tables are split into spring and summer flights due the seasonal variation of traffic.

Table 1 : Average occupancy for summer flights.

Frequency / assignation		08.2015	08.2016	07.2017	08.2018
136.975 MHz	CSC	20.35%	26.23%	31.02%	23.12%
136.875 MHz	SITA Ter.	1.84%	6.33%	8.69%	7.75%
136.825 MHz	ARINC E-R	0.02%	1.69%	0.00%	0.22%
136.775 MHz	SITA E-R	0.01%	0.63%	4.33%	4.53%
136.725 MHz	ARINC Ter.	0.40%	0.82%	3.01%	19.52%

Table 2 : Average occupancy for spring flights

Frequency / assignation		04.2017	05.2018	04.2019
136.975 MHz	CSC	18.82%	18.03%	23.59%
136.875 MHz	SITA Ter.	5.20%	6.80%	8.87%
136.825 MHz	ARINC E-R	0.31%	0.18%	0.00%
136.775 MHz	SITA E-R	1.29%	2.84%	8.97%
136.725 MHz	ARINC Ter.	1.49%	11.50%	17.43%

Note 1: The reader shall note that the occupancy measurement on the SITA Terminal frequency does not reflect the real behaviour of the channel due to the location of the monitoring receiver (aircraft at FL370). In order to have a correct

representation of the channel occupancy, the measurement would need to be done at the airport location (and is not in the scope of this document). However, average channel occupancy values are still presented in this report as they give information on the use of the frequency.

This phenomenon is not addressed on ARINC's terminal frequency because today this frequency is used for both en-route and terminal use. As soon as ARINC implements its dedicated en-route frequency, the same comments will also apply to ARINC's terminal frequency.

<u>Note 2:</u> The rise of the mean occupancy on the CSC is due to the voice interference that occurred during descent (UK border to AMS) as it will be seen in the next section.

4.1.2 One minute occupancy over time

Using an integration time of 60 seconds, the following graphs gives occupancy in function of time (flight path) for each frequency. The graph for the same period last year is also provided for comparison purposes.
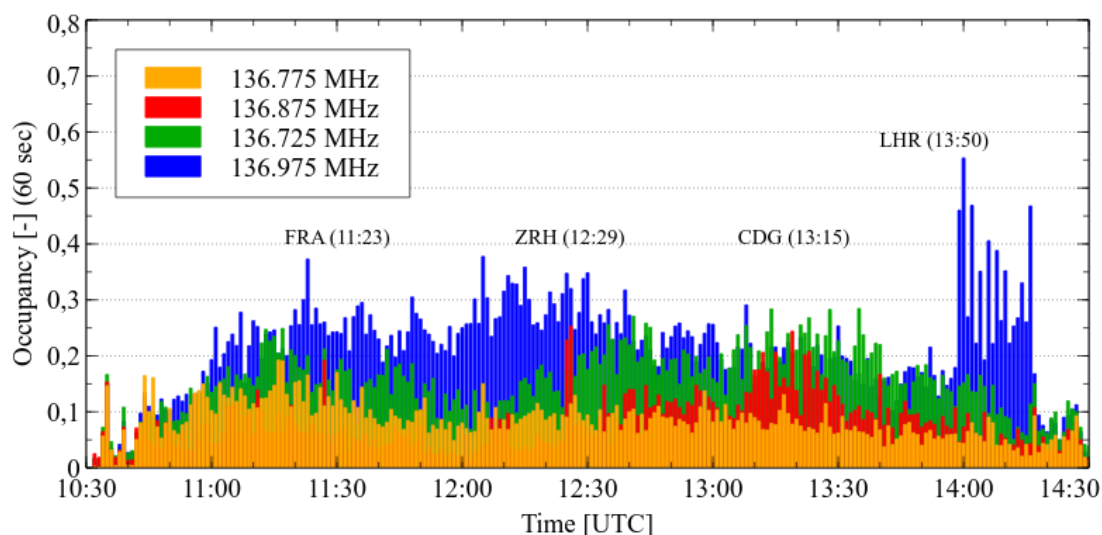
Figure 4-1 : Occupancy in function of time on 16/04/2019.

<u>Note:</u> The high values of occupancy on the CSC after London are caused by the voice interference observed during the 20 minutes of descent.
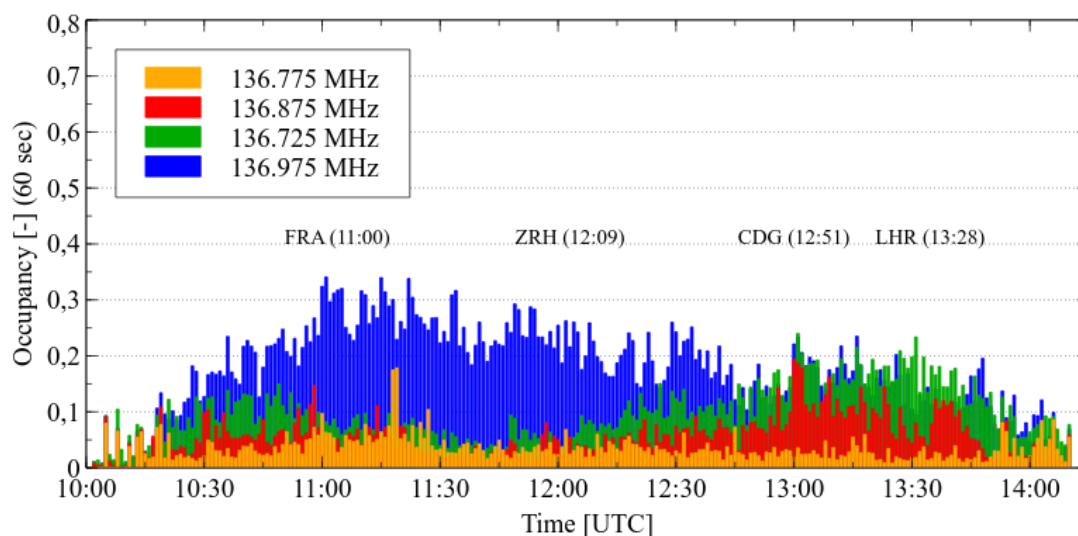
Figure 4-2 : Occupancy in function of time on 03/05/2018.

4.2   Airborne collision rate

Using a dataset of 120 one-second[4] of data, the collision rate is estimated by computing the ratio between the number of collided bursts over the total number of observed bursts. The values are summarized in the following table.

Table 3 : Collision rate for summer flights

Frequency / assignation		08.2015	08.2016	07.2017	08.2018
136.975 MHz	CSC	47.85%	42.57%	50.28%	37.10%
136.875 MHz	SITA Ter.	6.43%	16.31%	16.26%	15.82%
136.825 MHz	ARINC E-R	-	-	-	-
136.775 MHz	SITA E-R	-	-	7.52%	5.91%
136.725 MHz	ARINC Ter.	-	0.00%	9.92%	29.51%

[4] Since 2019 the one-second dataset have been extended to 180 (flight duration above FL285).

Table 4 : Collision rate for the spring flights

Frequency / assignation		04.2017	05.2018	04.2019
136.975 MHz	CSC	36.71%	37.48%	34.17%
136.875 MHz	SITA Ter	17.29%	15.43%	18.32%
136.825 MHz	ARINC E-R	-	-	-
136.775 MHz	SITA E-R	2.99%	5.49%	13.06%
136.725 MHz	ARINC Ter.	6.12%	20.73%	25.27%

Note 1: As mentioned earlier, the measurements on the SITA Terminal frequency do not reflect the real behaviour of the channel. The number of collisions as seen from the aircraft at FL370 is strongly overestimated when compared to the expected reality. We expect very few collisions on a terminal frequency at a specific airport as most aircrafts (on ground) and VGSs see each other whereas the airborne monitoring aircraft sees transmissions from all airport stations acting as hidden transmitters. However, the values are still presented as they are good examples of the hidden transmitter problem phenomenon.

Note 2: The reader shall note the significant increase of the collision rate on SITA en-route frequency.

Note 3: The reader should note a decrease in the collision rate on the CSC mainly due to the traffic offloading on the CSC. Unfortunately due to the voice interference on the CSC during descent, this decrease is not observable through the mean occupancy from table-2.

4.3 Channel use

This section presents statistics on how the traffic is distributed over the different channels depending on the type of frame sent. The analysis is performed only using correctly received AVLC frames during the full flight duration. All the following analysis is based on the frame size (bytes), not their number.

The traffic rate is expressed in kbits/s[5], and is computed using one-minute datasets of traffic along the flight duration. The one-minute integration time is chosen to reduce various "averaging" effects (time, location) that is observed if we use the aggregated data from the full flight when analysing the peak of the

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[5] The traffic rate is expressed as : $Rate\ [kbits/s] = 8 * \frac{Traffic\ [kB/minute]}{60}$

traffic[6]. The Median and the 95th percentile values are used to estimate the "mean" and "peak" traffic on the different channels.

Tabulated values related to the following graphs can be found in the annexe 2.

4.3.1   Share of channels by ACSPs

The following graphs summarizes the share of each channel by the service providers over time.
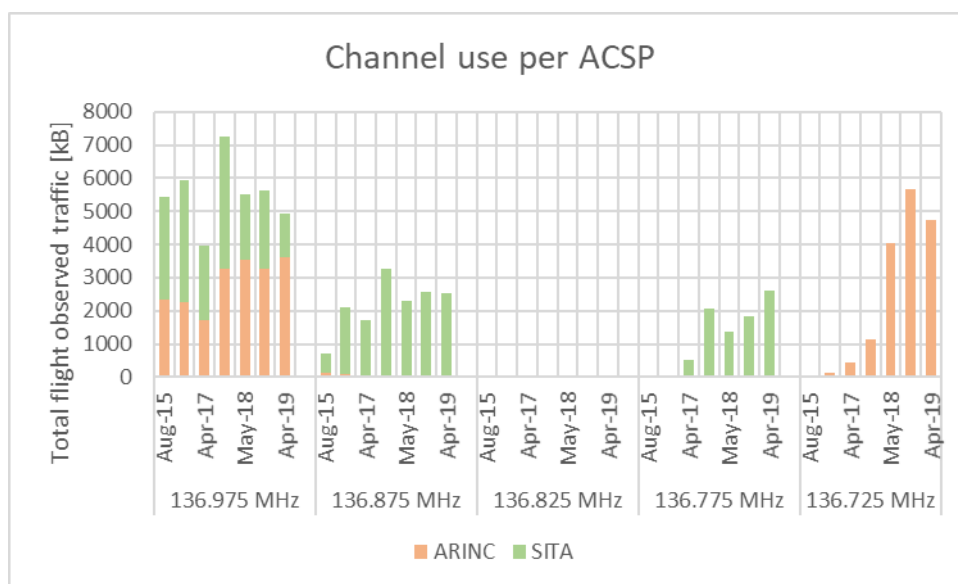
Figure 4-3 : Traffic distribution between ACSP per frequency

<u>Note</u>: The use of 136.875 MHz by both ACSP in 2015 and 2016 is due to the mixed used of the frequency prior to 2017.

The following graph focuses on the distribution of traffic between ACSPs on the CSC.

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[6] The observed traffic being a function of time and location, the monitoring aircraft flying across Europe above different locations will observe different traffic profiles. Moreover, some flights experienced interferences and/or corrupted data of various sources, hence reducing the total number of correctly received AVLC frame during the flight.
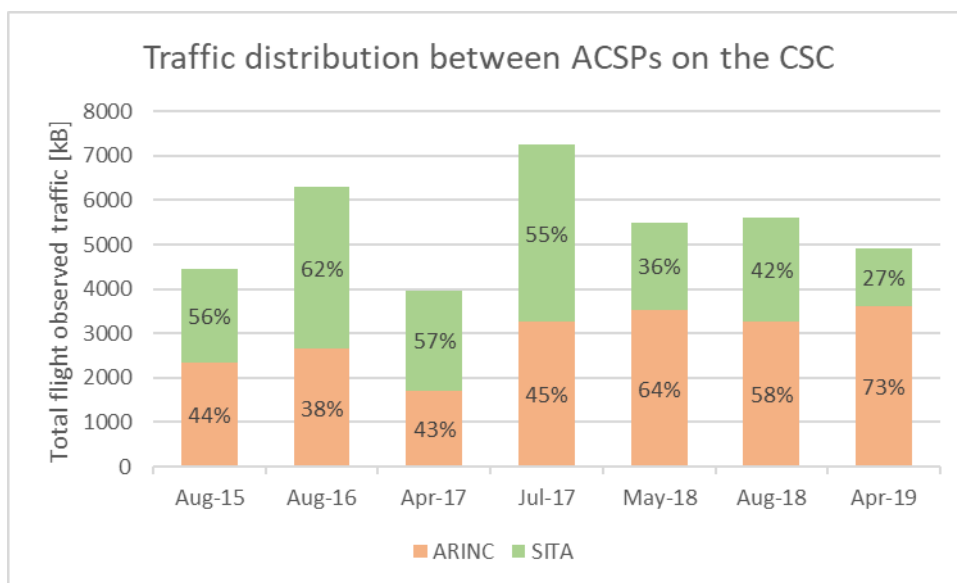
Figure 4-4 : Traffic distribution between ACSPs on the CSC

4.3.2   CSC offload

The following graph summarizes the percentage of traffic between the CSC and the alternate frequencies (the latter is split between the two ACSPs), highlighting the increase of traffic on the alternate frequencies.
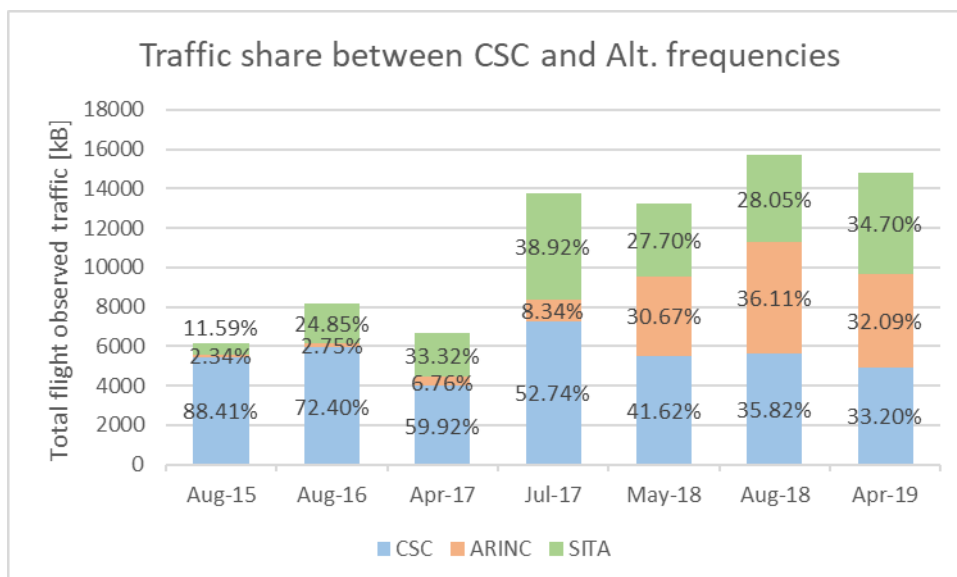
Figure 4-5 : Partition of the total traffic between the CSC and the alternate frequencies

The following graph displays the evolution of the total traffic volume heard during the monitoring flights for each ACSP between the CSC and the alternate frequencies (grouped) highlighting the percentage of traffic volume offloaded from the CSC for each ACSP.
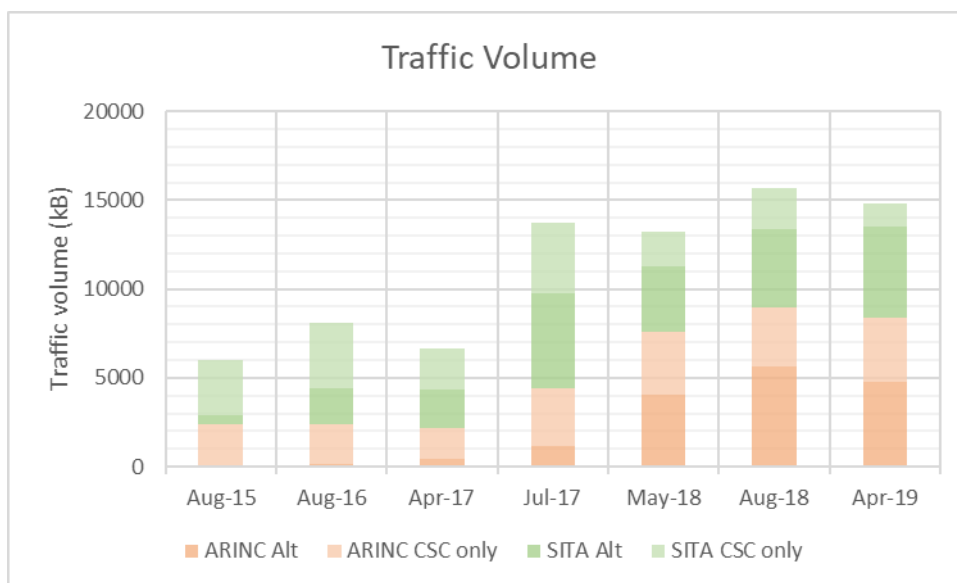
Figure 4-6 : Evolution of the traffic volume per ACSP between the CSC and Alternate frequencies

Note: 80% of the traffic volume heard on SITA's network is seen on alternate frequencies while 57% of the traffic volume heard on ARINC's network is seen on the alternate frequency.

The following graph shows the number of aircraft (unique ICAO 24-bits address) observed during the monitoring flight in function of the frequencies (CSC-alternates). It highlights the number of aircraft tuned to alternate frequencies in function of the monitoring flights. The number of aircraft only heard on the CSC is computed as the difference between the total number of aircraft heard (per ACSP) and the ones heard on alternate frequencies.
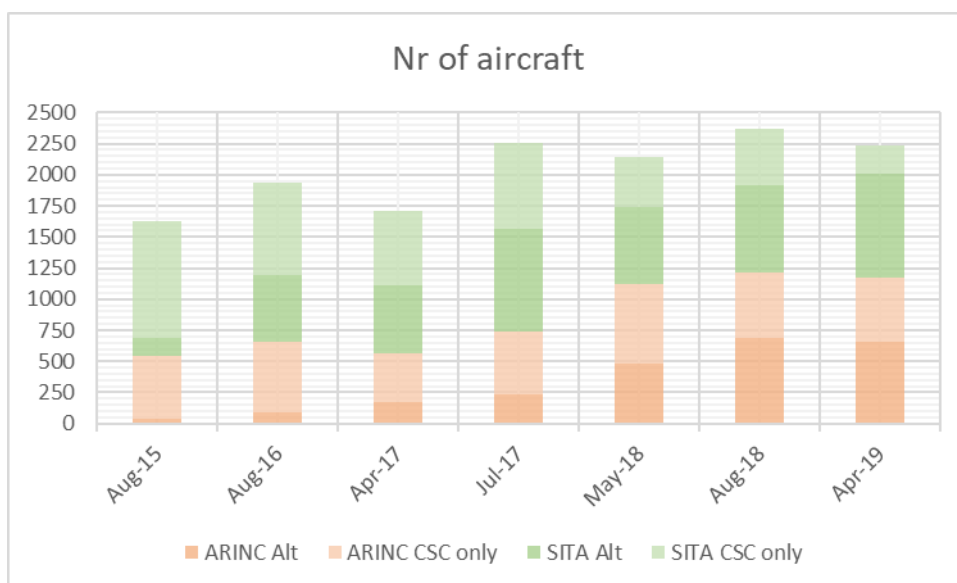
Figure 4-7 : Number of aircraft heard on alternate frequencies

Note 1: An aircraft only heard on the CSC does not mean it is not multi-frequency capable.

Note 2: 78% of the aircraft (unique ICAO 24-bits address) on SITA's network were heard on alternate frequencies while 56% of the aircraft (unique ICAO 24-bits address) on ARINC's network were heard on an alternate frequency. Looking at all the aircraft (both ACSPs), 66% of them are heard on alternate frequencies.

Note 3: The growth of the total number of aircraft heard during the 4 hrs of monitoring flight has been reduced to a yearly average of 4.7% since 2017 while the growth was observed to be 17.6% between 2015 and 2017.

4.3.3   Distribution of AVLC frame by type

The following graphs shows the distribution of the AVLC frame types computed over all the frequencies and for the flight duration. AOA frames convey ARINC-620 packets, X.25 frames convey ATN packets, while "Misc." frames convey AVLC protocol related packets (RR, SREJ, XID,…). Graphs are provided for all the channels and for the frequencies conveying E-R traffic only (as discussed in [8]).

Note: 45% of the AVLC protocol related frames conveys RR frames. These could be equally split into AOA and X.25 traffic as they are directly related to the transfer of these frames at the AVLC layer but are kept into a separate category as they do not specifically convey AOA or X.25 data.

Figure 4-8 : AVLC frame distribution over time
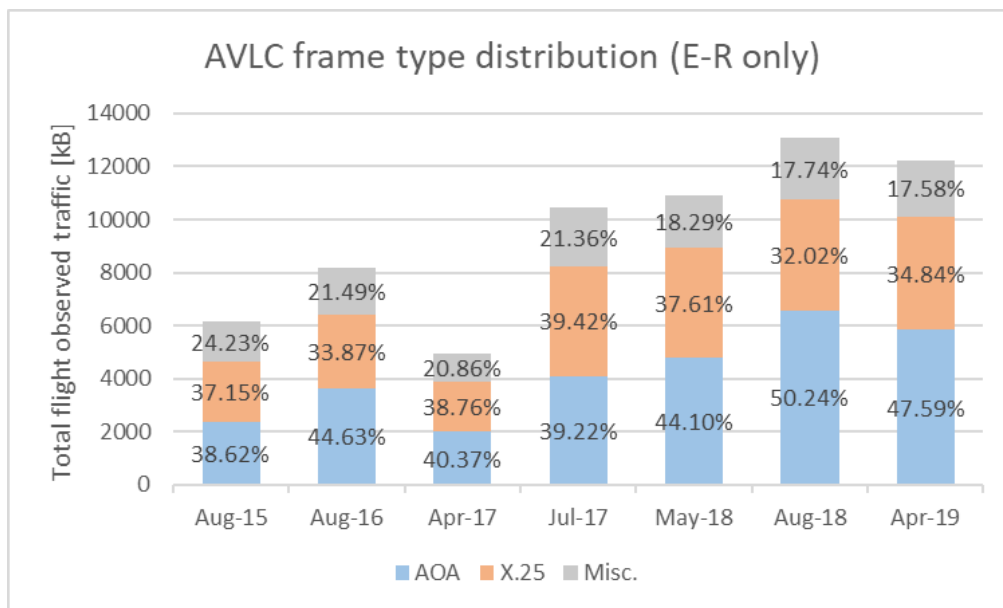
Figure 4-9: AVLC frame distribution over time for frequencies conveying E-R traffic
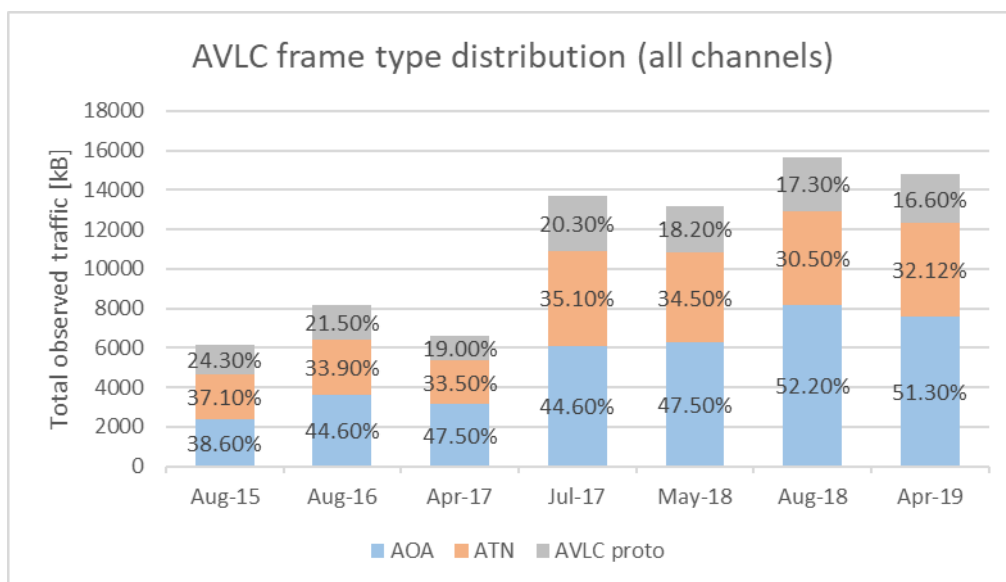
Note 1: An increase of 12% of the global traffic is observed between May 2018 and April 2019.

Note 2: AOA is responsible for 60% of the global traffic volume observed.

4.3.4   AOA traffic

The following graph displays AOA traffic based on the ACARS labelling, providing hence the evolution of AOA traffic depending on the service type. The ACARS message types are grouped into the following categories in order to ease the analysis.

- The "protocol" category groups ACARS protocol related message that are mainly composed of acknowledgement blocks;

- "Link test" messages refers to ACARS link test messages mainly observed each time the aircraft makes an hand-over;

- "Peripheral H1" refers to ACARS messages sent/received to/from a peripheral[7] to the ACARS Management Unit (MU);

- "FIS" messages refers to Flight Information Services messages;

- "Predefined" messages are user-defined messages not standardized within ACARS specifications – their content cannot be analysed;

- "Remaining" messages refers to messages not belonging to the previous categories.
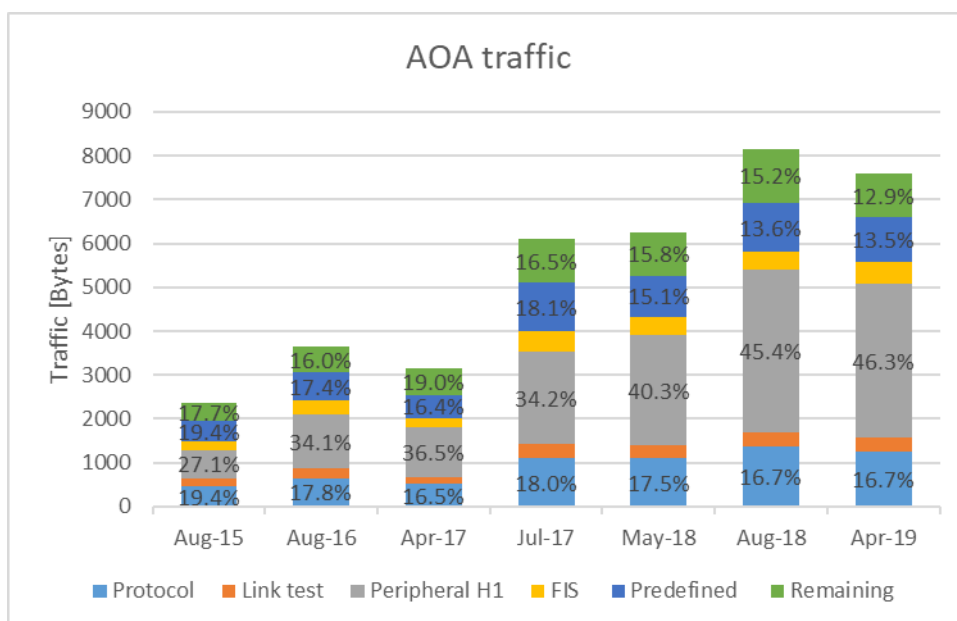
Figure 4-10 : AOA traffic repartition

Note: The main increase of AOA traffic volume is due to "Peripheral H1" messages.

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[7] Typically, these subsystems include (not exhaustive) the Optional Auxiliary Terminal (OAT), the Flight Management Computer (FMC), the Aircraft Condition Monitoring System (ACMS), and MIAM peripheral.

4.3.5 Global peak and median traffic rate (kbits/s) per AVLC frame type

The following graphs shows the median and 95th percentile traffic rate for the three categories of AVLC frames computed over all the frequencies. Graphs are provided for all the channels and for the frequencies conveying E-R traffic only (as discussed in [8]).
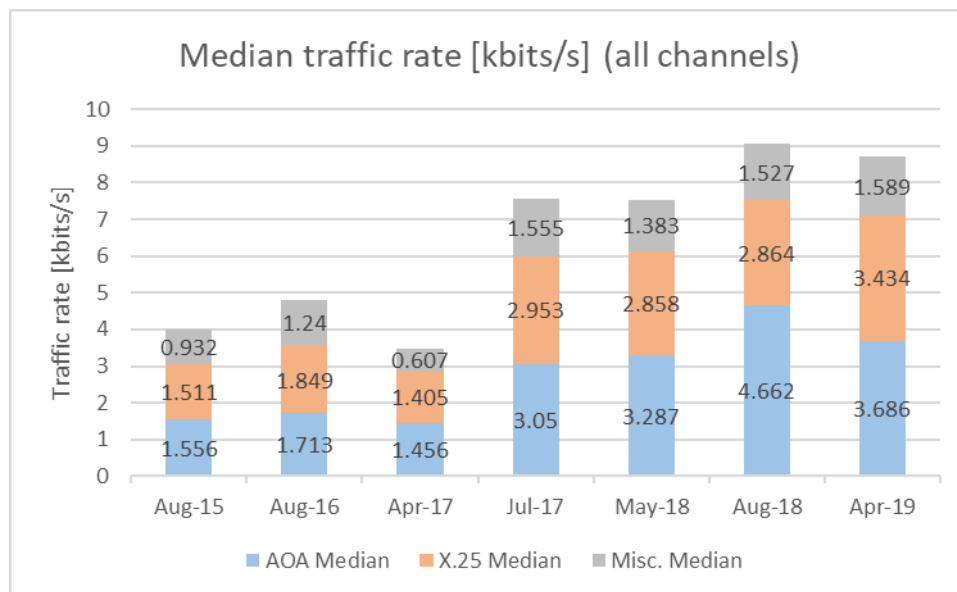
Figure 4-11 : Median traffic rate
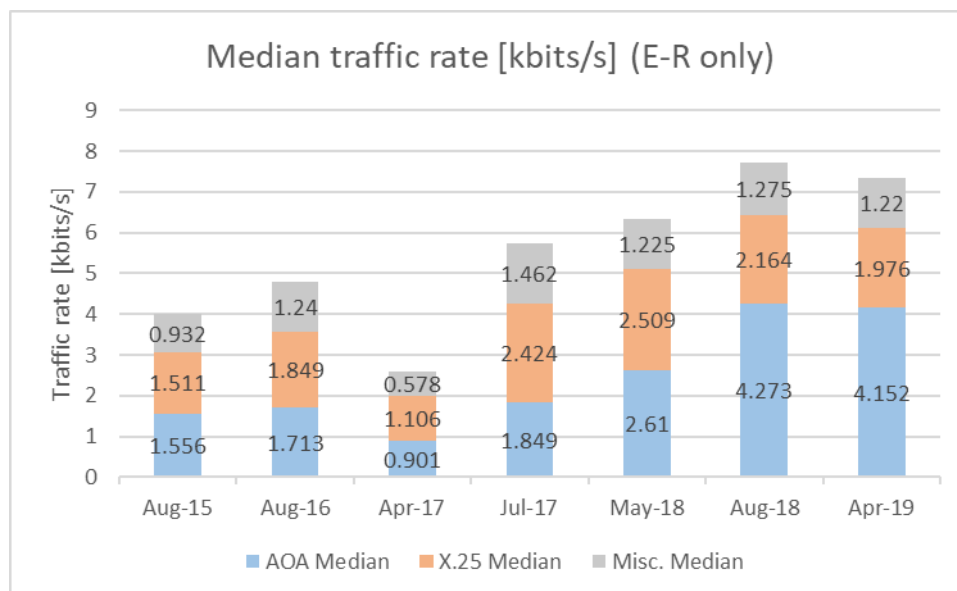
Figure 4-12: Median traffic rate for frequencies conveying E-R traffic

95th percentile traffic rate [kbits/s] (all channels)
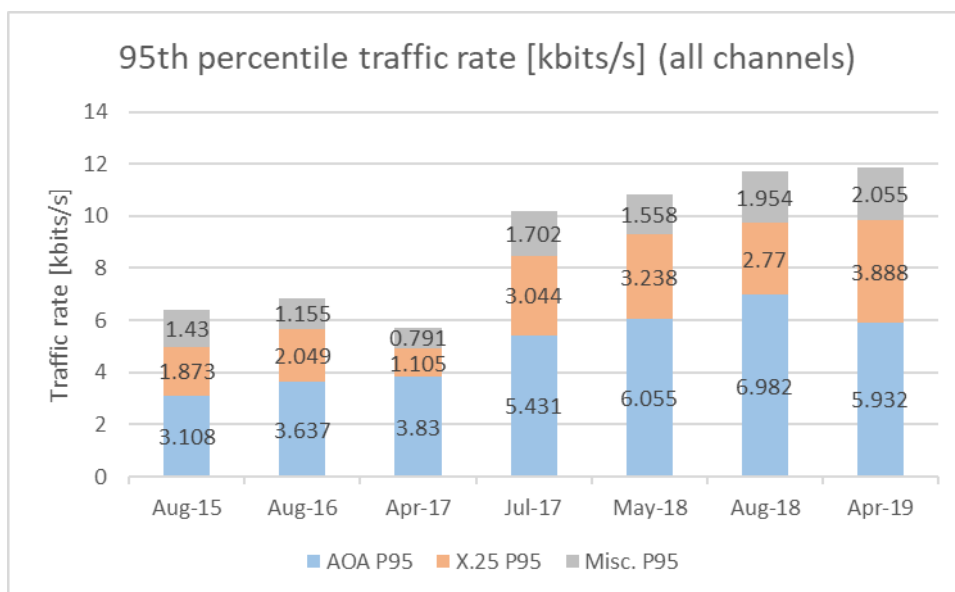
Figure 4-13 : 95th percentile traffic rate

95th percentile traffic rate [kbits/s] (E-R only)
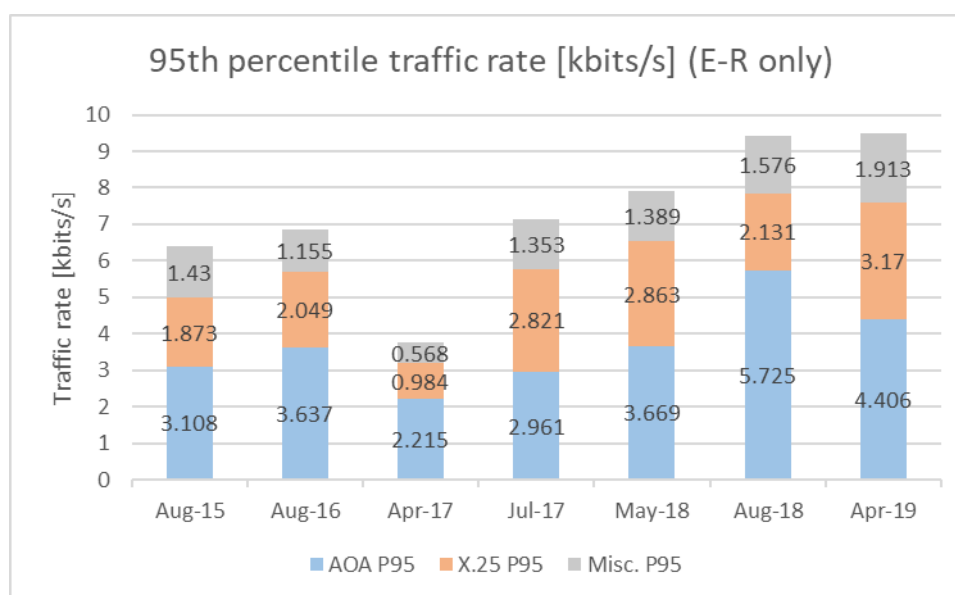
Figure 4-14: 95th percentile traffic rate for frequencies conveying E-R traffic

Note: An increase of 15.7% (all channels) and 15.7% (E-R only) of the median traffic rate is observed between May 2018 and April 2019. The increase of the 95th percentile is 9.4% (all channels) and 19.8% (E-R only).

4.3.6 Channel throughput

The following graphs shows the peak and median channel[8] throughputs (kbits/s) measured per frequency over a one-minute time window.
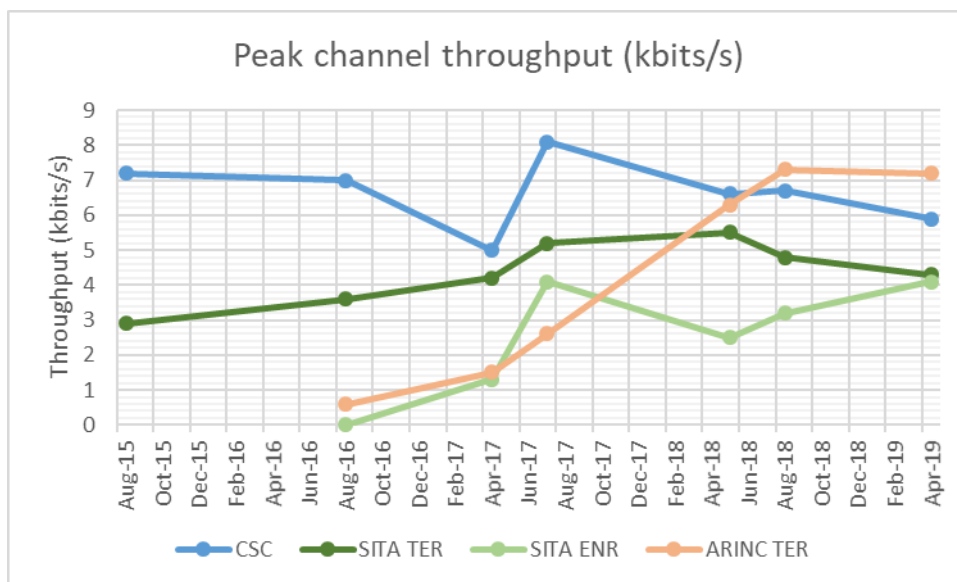
Figure 4-15 : Peak channel throughput
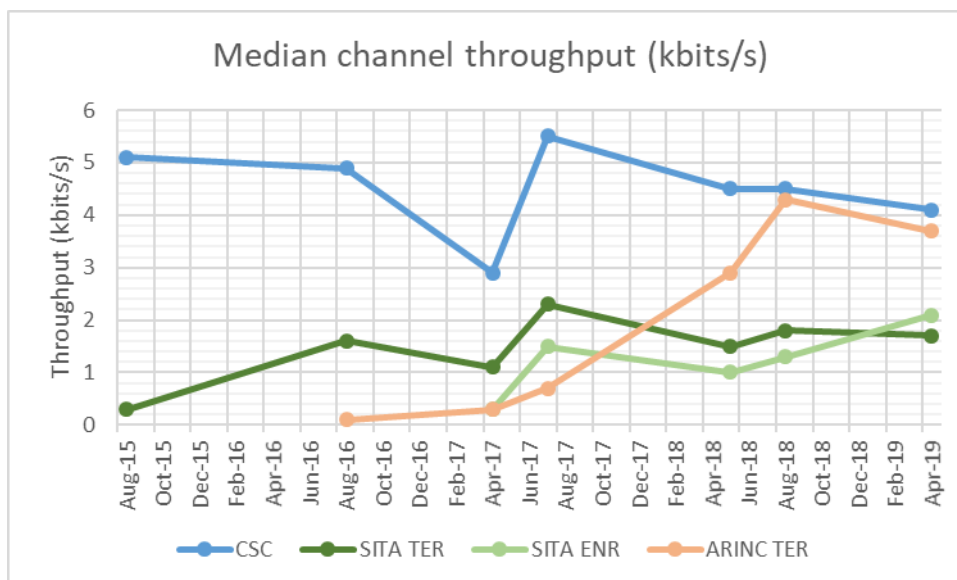
Figure 4-16 : Median channel throughput

<u>Note 1</u>: The throughput on the CSC (both peak and median) is decreasing since July 2017. This is mostly due to the offloading of the CSC

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[8] We consider here the bust length instead of the AVLC size.

4.4 Interferences

The same kind of interferences as seen during the previous monitoring flights were observed across the VDL band.

The following table summarizes the duration (MM:SS) of the interferences over the full flight duration.

Table 5 : Interference duration summary

	08.2015	08.2016	04.2017	07.2017	05.2018	08.2018	04.2019
Modulated voice signals	02:58	21:04	01:42	01:54	01:43	01:46	11:14
RTTY-like signals	00:34	00:14	02:27	00:28	01:00	00:00	00:00
5-tones selcall				00:23	00:42	00:48	00:22
Industial noise-like	34:56	12:59	04:32	10:36	07:45	07:53	09:54
Total	*38:53*	*34:17*	*08:41*	*13:21*	*11:10*	*10:27*	*21:30*

<u>Note</u>: The satellite signals are no longer displayed nor analysed as their presence is known, regular and predictable[9]. The two satellites identified by the Leeheim (D) satellite monitoring station in 2015 have an average pass of 2 hours every 60 hours each, resulting in an interfering signal to be present about 3.3% of the time.

4.4.1 Modulated voice signals

Voice communications are still present on the VDL band. The following tables summarizes their duration according to the channels they were observed on.

Table 6 : Modulated voice signal duration summary

	N. of transmissions	Duration (MM:SS)	Notes
136.975 MHz	161	05:48	CSC
136.950 MHz	8	00:16	Guard channel
136.912 MHz	102	03:55	Guard channel
136.875 MHz	4	00:22	SITA Ter.
136.800 MHz	24	00:53	Guard channel

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[9] The satellite passes can be computed using NORAD TLEs. A Two Line Element set (TLE) is a data format to encode orbital elements of an earth-orbiting object within two lines of ASCII text and used to estimate the position of the object using prediction formulae. The North American Aerospace Defence Command (NORAD) tracks all detectable earth-orbiting objects and the non-classified objects TLEs are made available on the website: https://www.celestrak.com/NORAD/elements/.

5 Conclusions

This report presents the results of the 7th monitoring flight that took place on April 16th 2019.

The key points are summarized hereafter and further discussed in the following paragraphs:

1. 67% of the observed traffic volume is now taking place on the alternate frequencies.

2. An increase of 12% of the traffic volume is observed between May 2018 and April 2019.

3. The traffic volume on the CSC is split 73% ARINC and 27% SITA.

4. The traffic on the CSC is continuously decreasing since July 2017.

5. 78% of the aircrafts on SITA's network are observed on its alternates frequencies while 56% for ARINC.

6. AOA represent 60% of the global traffic volume.

7. The median traffic rate increased by 15.7% between May 2018 and April 2019.

8. Voice communication are still heard on VDL2 frequencies.

Multi-frequency deployment

The multi-frequency deployment is still on-going and 67% of the observed traffic volume is now being performed on the alternate frequencies

The traffic on the CSC is continuously decreasing since July 2017. The median measured throughput has fallen from 5.5 kbits/s in July 2017 to 4.1 kbits/s.

The number of aircraft heard on the alternate frequencies has increased and represent today 66% (78% for SITA and 56% for ARINC).of the total number of aircraft heard during the monitoring flight.

Traffic volume

An increase of 12% of the global traffic volume is observed between May 2018 and April 2019 (section 4.3.3).

80% of the traffic volume heard on SITA's network is exchanged on its alternate frequencies. 57% of the traffic volume heard on ARINC's network is exchanged on its alternate frequency.

AOA traffic represents 60% of the global traffic volume observed (section 4.3.3).

The median of the global traffic rate has increased by 15.7% between May 2018 and April 2019 (section 4.3.5).

Interferences

A significant voice interference was heard on the CSC during the 20 minutes of descent to AMS. It is by far the most important one observed since 2015. A probable interferer has been identified and notified to the appropriate body.

6   REFERENCES

[1] Ch. VISEE, VDL2 Flight test analysis for EUROCONTROL CRO, Preliminary report, C.C.R.M., 2015.

[2] Ch. VISEE, VDL2 Flight test analysis for EUROCONTROL CRO – 2016 test flight analysis – Comparison with 2015 results, C.C.R.M., 2016

[3] Ch. VISEE, VDL2 Flight test analysis for EUROCONTROL CRO – April 2017 monitoring flight and comparison with previous flights, C.C.R.M., 2017

[4] Ch. VISEE, VDL2 Flight test analysis for EUROCONTROL DMPF – July 2017 monitoring flight and comparison with previous flights, C.C.R.M., 2017

[5] D. Isaac, The DPMF report catalogue, v0.2, 2019

[6] ICAO, Annex 10 to the convention on international civil aviation: Volume III Communication systems, July 2007.

[7] ICAO, AUR Frequency Management Manual for Aeronautical Mobile and Aeronautical Radio Navigation Services – ICAO EUR Doc 011 (2017), edition Dec.2017.

[8] Ch. VISEE, DMPF VDL 2 MONITORING FLIGHT REPORT, May 2018 DPMF test flight, July 2018.

[9] Ch. VISEE, VDL2 TRAFFIC MODELING AND FORECASTING, Methodology proposal and initial results, March 2019.

7   ABBREVIATIONS

Abbreviations and acronyms used in this document are available in the EUROCONTROL Air Navigation Inter-site Acronym List (AIRIAL) which may be found here:

http://www.eurocontrol.int/airial/definitionListInit.do?skipLogon=true&glossaryUid=AIRIAL

Annex 1 - Measurement setup

The measurement system provided by C.C.R.M.[10] contains a *Rhode & Schwarz* EM100 receiver connected to the DM C50-17 antenna located at the bottom rear of the fuselage (RH side), through a 3dB splitter and a tuneable band pass filter of 10%. Acquisition is performed using a laptop connected to the receiver and consist on IQ data recordings over a bandwidth of 500 kHz centred on 136.8375 MHz[11]. The 4 hours of flights provided about 40 GB of data. IF-PAN spectrum data of 10 MHz were also recorded[12].

The following summarizes the main receiver settings:

Centre Frequency	**136.8375 MHz**
IQ bandwidth	500 kHz
Sampling rate	640 kS/s
AGC	OFF
Reference level	50 dBµV
Attenuation	OFF

The cable losses are summarized in the following table.

	Losses
C.C.R.M. measurement box (splitter, filter, cables)[13].	7 dB
Receiver-to-Plane RF cable (Suhner S 06132 D-10) (12m).	1.17 dB
Fuselage RF cables to antenna[14].	2.3 dB

Note: *Except elsewhere stated, level values used in this report refer only to the receiver's level without taking into account the losses from the previous table. The latter's are used to compute the level at the antenna port.*

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[10] Centre de Contrôle des Radiocommunications des services Mobiles (BE)

[11] This is the centre frequency of the VDL band.

[12] EM100 is capable of providing 10MHz of spectrum data centred on the receiver's frequency with a resolution bandwidth of 6.25 kHz. The latter is used for interference analysis coming from upper or lower the VDL band.

[13] Measured on April 13th, 2018. Previously measured 6.5 dB on May 20th, 2017.

[14] Measured by NLR in August 2017.

Annex 2 - Tabulated values of chapter 3

A1.1 Service provider related data

Table 7 : Traffic partition per ACSP and per frequency for the summer flights

Frequency / assignation			08.2015	08.2016	07.2017	08.2017
136.975 MHz	CSC	(ARINC)	44%	38%	45%	58%
		(SITA)	56%	62%	55%	42%
136.875 MHz	SITA Ter.		80%	96%	100%	100%
		(ARINC)	20%	4%	0%	
136.825 MHz	ARINC E-R		-	-	-	-
136.775 MHz	SITA E-R		-	-	100%	100%
136.725 MHz	ARINC Ter.		-	100%	100%	100%

Table 8 : Traffic repartition per ACSP and per frequency for the spring flights

Frequency / assignation			04.2017	05.2018	04.2019
136.975 MHz	CSC	(ARINC)	43%	64%	73%
		(SITA)	57%	36%	27%
136.875 MHz	SITA Ter.		100%	100%	100%
136.825 MHz	ARINC E-R		-	-	
136.775 MHz	SITA E-R		0%	100%	100%
136.725 MHz	ARINC Ter.		100%	100%	100%

Table 9 : Global traffic partition per ACSP

Provider		08.2015	08.2016	04.2017	07.2017	05.2018	08.2018	04.2019
GLOBAL	CSC	89%	72%	60%	53%	42%	36%	33%
	Alt.	11%	28%	40%	47%	58%	64%	67%
ARINC	CSC	93%	91%	79%	74%	47%	37%	43%
	Alt.	7%	9%	21%	26%	53%	63%	57%
SITA	CSC	82%	64%	51%	43%	35%	35%	20%
	Alt.	18%	36%	49%	57%	65%	65%	80%

A1.2 Number of station heard and their generated traffic

The following table summarizes, for each channel, the number of station heard (airborne/grounded aircraft, VGSs) and their respective generated traffic.

Table 10 : Number of station and their generated traffic per frequency and per station type

		08.2015	08.2016	04.2017	07.2017	05.2018	08.2018	04.2019
136.975 MHz CSC	AIR	1284	1628	1356	1742	1511	1558	1381
		2537 kB	3758 kB	1960 kB	4326 kB	3014 kB	3198 kB	2890 kB
	GND	411	472	365	525	487	492	460
		283 kB	283 kB	327 kB	465 kB	480 kB	458 kB	409 kB
	VGS	69	88	79	88	97	107	102
		1749 kB	1892 kB	1689 kB	2452 kB	2011 kB	1962 kB	1620 kB
136.875 MHz SITA Ter.	AIR	63	223	238	412	368	398	400
		135 kB	354 kB	255 kB	666 kB	841 kB	874 kB	801 kB
	GND	127	434	334	536	284	303	351
		247 kB	901 kB	814 kB	1317 kB	757 kB	831 kB	815 kB
	VGS	18	29	24	28	25	26	25
		330 kB	857 kB	637 kB	1277 kB	693 kB	868 kB	934 kB
136.775 MHz SITA E-R	AIR	0	0	169	443	390	466	673
		0 kB	0 kB	269 kB	1166 kB	915 kB	1302 kB	1854 kB
	GND	0	0	22	52	15	20	14
		0 kB	0 kB	33 kB	105 kB	8 kB	23 kB	20 kB
	VGS	0	1	11	16	17	20	17
		0 kB	3 kB	202 kB	814 kB	451 kB	501 kB	719 kB
136.725 MHz ARINC Ter.	AIR	0	61	166	232	467	662	623
		0 kB	83 kB	250 kB	753 kB	2415 kB	3158 kB	2557 kB
	GND	0	9	26	45	163	233	253
		0 kB	1 kB	6 kB	12 kB	345 kB	742 kB	690 kB
	VGS	0	5	7	7	11	13	16
		0 kB	60 kB	192 kB	380 kB	1296 kB	1763 kB	1509 kB

A1.3 Partition of AVLC frame type

The following table summarizes, for the four channels, the repartition of AVLC frame type. AOA frames convey ARINC-620 packets, X.25 frames convey ATN packets, while "Misc." frames convey AVLC protocol related packets (RR, SREJ, XID,…).

Table 11 : Traffic repartition per frequency and AVLC frame type

		08.2015	08.2016	04.2017	07.2017	05.2018	08.2018	04.2019
136.975 MHz CSC	AOA	37.2%	38.1%	38.9%	36.3%	42.9%	45.6%	47.4%
	X.25	38.9%	38.1%	39.7%	41.1%	37.1%	34.1%	32.7%
	Misc.	23.9%	23.8%	21.4%	22.5%	20.0%	20.3%	19.8%
136.875 MHz SITA Ter.	AOA	52.5%	62.4%	67.6%	61.4%	63.2%	62.1%	69.3%
	X.25	26.3%	21.2%	18.3%	21.4%	20.2%	22.8%	18.7%
	Misc.	21.2%	16.4%	14.1%	17.2%	16.6%	15.1%	11.9%
136.775 MHz SITA E-R	AOA	-	0%	52.9%	49.5%	38.5%	48.7%	40.1%
	X.25	-	0%	25.1%	29.8%	38.4%	31.1%	40.2%
	Misc.	-	100%	22.0%	20.8%	23.1%	20.1%	19.7%
136.725 MHz ARINC Ter.	AOA	-	31.6%	35.3%	35.8%	47.5%	55.3%	51.8%
	X.25	-	41.6%	45.3%	46.0%	37.8%	30.3%	34.1%
	Misc.	-	26.7%	19.4%	18.2%	14.7%	14.4%	14.1%

The following table summarizes the global repartition of the AVLC frame types, all channels confound. For the AOA type, the proportion for ARINC and SITA is provided between brackets.

Table 12 : Global traffic repartition per AVLC frame type

	08.2015	08.2016	04.2017	07.2017	05.2018	08.2018	04.2019
AOA (ARINC - SITA)	38.6% (11.2%-27.4%)	44.6% (12.0%-32.6%)	47.5% (12.4%-35.1%)	44.6% (11.8%-32.9%)	47.5% (28.3%-19.2%)	52.2% (31.1%-21.1%)	51.3% (29.0%-22.3%)
X.25	37.1%	33.9%	33.5%	35.1%	34.5%	30.5%	32.1%
Misc.	24.3%	21.5%	19.0%	20.3%	18.2%	17.3%	16.6%

A1.4 Global peak and median traffic rate (kbits/s) per AVLC frame type

Rate in kbits/s		08.2015	08.2016	04/2017	07.2017	05.2018	08.2018	04.2019
Global	P95	6.411	6.841	5.726	10.178	10.851	11.706	11.875
	Median	4.000	4.803	3.469	7.558	7.528	9.053	8.709
AOA	P95	3.108	3.637	3.830	5.431	6.055	6.982	5.932
	Median	1.556	1.713	1.456	3.050	3.287	4.662	3.686
X.25	P95	1.873	2.049	1.105	3.044	3.238	2.770	3.888
	Median	1.511	1.849	1.405	2.953	2.858	2.864	3.434
Misc.	P99	1.430	1.155	0.791	1.702	1.558	1.954	2.055
	Median	0.932	1.240	0.607	1.555	1.383	1.527	1.589

A1.5 Peak and median traffic rate (kbits/s) per frequency and per AVLC frame type

The following table displays the traffic rate for the P95th/median traffic minute computed from the total traffic within each minute (all frequencies). Each set (P95th/Median) comes from two different minutes of the flight explaining why some traffic rate on some frequencies/AVLC type might be greater for the median than the P95th.

Peak rate in kbits/s			08.2015	08.2016	04.2017	07.2017	05.2018	08.2018	04.2019
136.975 MHzc (CSC)	Global	P95	5.162	4.335	2.152	4.070	3.834	3.469	3.511
		Median	2.787	4.200	2.029	3.860	3.715	4.355	3.663
	AOA	P95	2.169	1.674	0.878	1.385	1.712	1.657	1.781
		Median	0.920	1.447	0.638	1.293	1.561	1.916	1.280
	X.25	P95	1.764	1.743	0.776	1.802	1.502	1.075	1.051
		Median	1.164	1.660	1.000	1.664	1.495	1.556	1.548
	Misc.	P95	1.229	0.918	0.498	0.883	0.620	0.736	0.679
		Median	0.703	1.094	0.392	0.903	0.659	0.884	0.835

136.875 MHz (SITA Ter).	Global	P95	1.249	2.422	2.631	2.034	2.446	2.276	2.257
		Median	1.213	0.566	1.044	2.041	0.946	1.104	1.472
	AOA	P95	0.939	1.938	2.330	1.171	1.908	1.249	1.499
		Median	0.637	0.256	0.706	1.246	0.600	0.871	1.224
	X.25	P95	0.109	0.273	0.142	0.495	0.287	0.653	0.439
		Median	0.347	0.166	0.215	0.521	0.173	0.140	0.107
	Misc.	P95	0.201	0.212	0.159	0.368	0.251	0.375	0.319
		Median	0.229	0.144	0.124	0.274	0.173	0.094	.0141
136.775 MHz (SITA E-R)	Global	P95	-	-	0.727	3.329	0.638	0.872	2.080
		Median	-	-	0.117	0.544	0.955	0.656	2.153
	AOA	P95	-	-	0.576	2.535	0.226	0.449	0.670
		Median	-	-	0.040	0.119	0.186	0.125	0.600
	X.25	P95	-	-	0.093	0.442	0.275	0.216	0.956
		Median	-	-	0.037	0.252	0.454	0.263	1.163
	Misc.	P99	-	-	0.058	0.351	0.137	0.207	0.464
		Median	-	-	0.039	0.173	0.315	0.269	0.389
136.725 MHz (ARINC Ter).	Global	P95	-	0.084	0.215	0.745	3.932	5.089	4.026
		Median	-	0.037	0.279	1.113	1.192	2.937	1.421
	AOA	P95	-	0.025	0.046	0.340	2.208	3.627	1.982
		Median	-	0.011	0.073	0.392	0.939	1.751	0.582
	X.25	P95	-	0.033	0.094	0.305	1.173	0.826	1.441
		Median	-	0.023	0.153	0.516	0.736	0.906	0.616
	Misc.	P95	-	0.026	0.076	0.100	0.551	0.636	0.603
		Median	-	0.003	0.053	0.205	0.237	0.280	0.224

A1.6   Global peak and median traffic evolution per AVLC frame type for the summer flights

| Peak		08.2015	08.2016	07.2017	08.2018
Global growth	P95	-	6.7%	48.8%	15.0%
	Median	-	20.1%	57.4%	19.8%
AOA growth	P95	-	17.0%	49.3%	28.6%
	Median	-	10.1%	78.1%	52.9%
X.25 growth	P95	-	14.9%	48.6%	-9.0%
	Median	-	22.4%	59.7%	-3.0%
Misc. growth	P95	-	-19.2%	47.4%	14.8%
	Median	-	33.0%	25.4%	-1.8%

Annex 3 - Receiver level PDF and CDF curves

The following graphs provides with the PDF and CDF of the receiver's level. Occupancy at a specific level threshold can be calculated using the following formula:

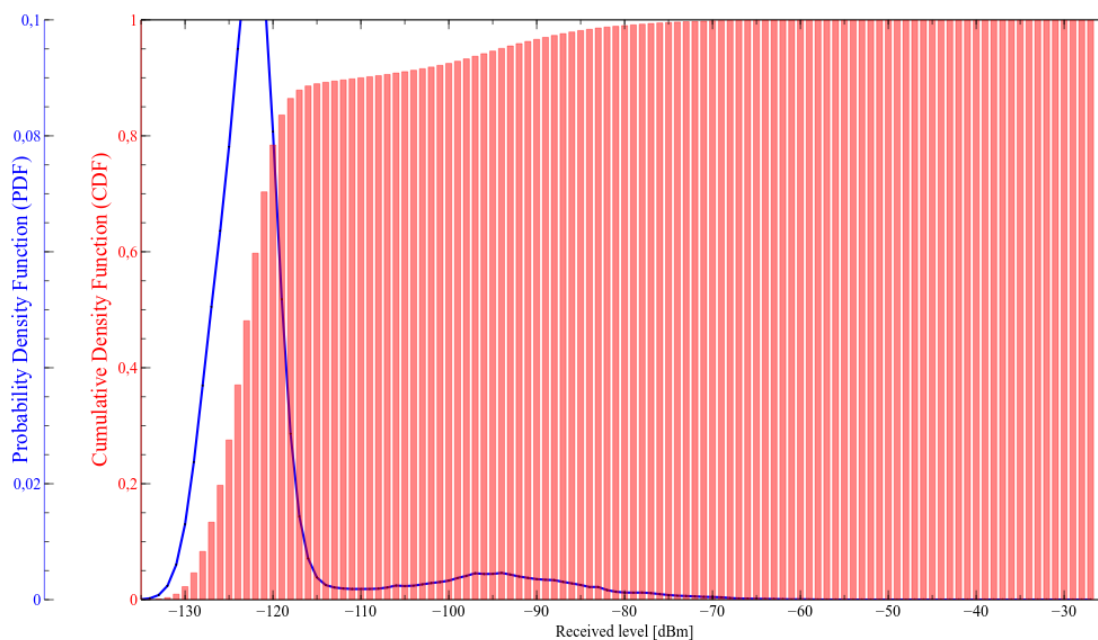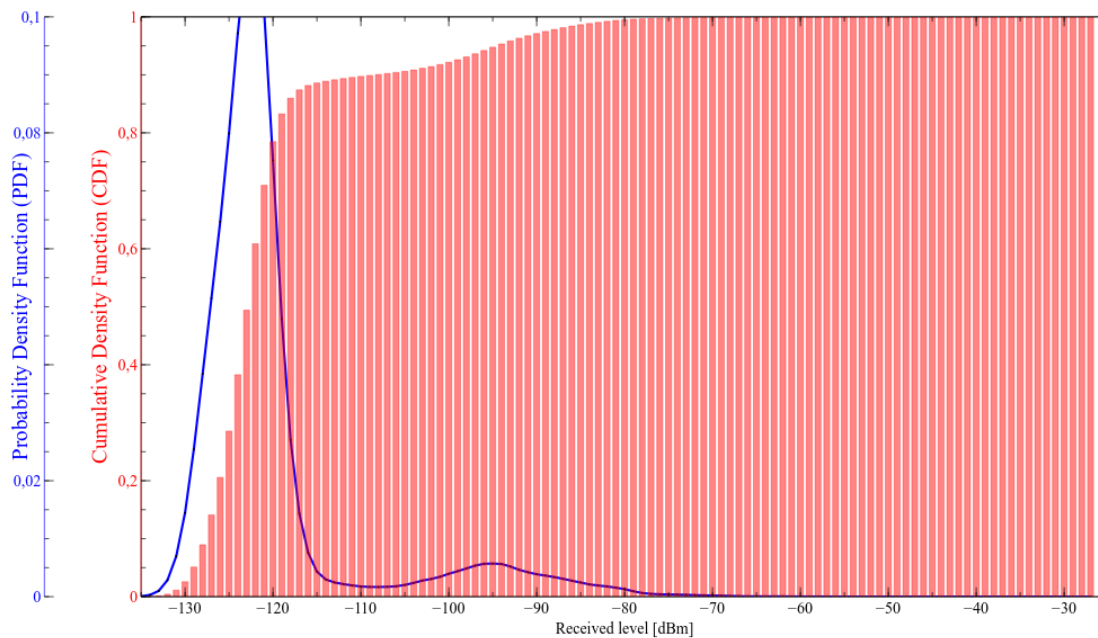$$Occupancy\ [-] = 1 - CDF(Level_{threshold}\ [dBm])$$

A1.7 136.975 MHz
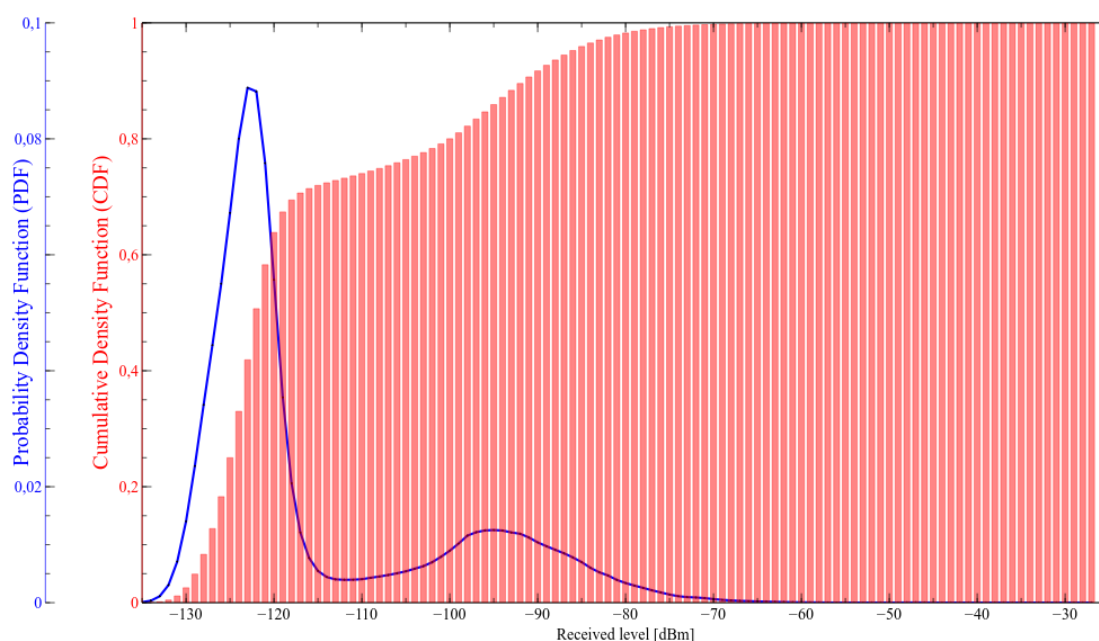
A1.8   136.875 MHz

A1.9   136.775 MHz

A1.10 136.725 MHz

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