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Sound pressure levels inside the cabins of the AS350 B2 and AW119 MkII rotary-wing aircraft during SAR operations

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Abstract

High SPLs inside helicopters are of concern, but, to date, there is very little specific data on noise exposure of helicopter crews in SAR and aeromedical missions. In aeromedical and rescue operations crew and patients are subject to flight configurations that are very different from that performed by conventional aviation. Operation inside the "Dead Man's Curve", with live cargo hanging, close to the MTOW or open doors is frequent. As flight patterns directly influence interior SPLs, more detailed noise measurements inside helicopters during such operations are required. To investigate the internal noise patterns of the public helicopter fleet of the state of Santa Catarina's AS 350 and AW 119 models during Rescue and Transport missions, four different AS 350 B2 and one AW 119 MkII were equipped with recording equipment (microphone and SQuadriga II) and flown repeatedly under mission-specific operational conditions. Mean LpAeq in AS350 aircraft (8 measurements) ranged from 89dBA@40kt to 95dBA@110kt (doors closed [DC]) and 95dBA@40kt to 99dBA@110kt (left rear door open). LpAeq standard deviation ranged from 1dB@different speeds to 3 dB@60kt. Mean LpCeq in AS350 aircraft (8 measurements) ranged from 106dBC@40kt to 110dBA@110kt (DC) and 117dBC@40kt to 124dBC@110kt (left rear door open). LpCeq standard deviation ranged from 1dB to 3 dB. In the AW119 (3 measurements) mean LpAeq ranged from 95 dBA@40kt to 102dBA@140kt (DC) and 96dBA@40kt to 99dBA@80kt (both rear doors open). Mean LpCeq ranged from 106dBC@hovering OGE to 119dBC@140kt (DC) and 108dBC@hovering OGE to 116dBC@different conditions (rear doors open). Standard deviations were 1 to 6dB, largest at take-off. Flying with open doors increased A-weighted SPLs up to 7 dB in AS350B aircraft and 9 dB in AW119 aircraft. Increase of C-weighted SPLs was found to be up to 15 dB in AS350 and 6dB in AW119.

Keywords: acoustics, helicopter, noise, aeromedic, operations.

PACS: 43.50.Rq, 43.50.Lj .



1. INTRODUCTION

The high sound pressure levels produced by helicopters are widely known, but to date, there is very little specific data on the sound pressure levels helicopter rescue and aeromedical transport teams are subject to. In this context it is interesting to note that in air medical rescue and transport operations, the exposure of crew and patients to sound pressure levels differs from the exposure of a crew on air taxi or private flights. This difference is primarily caused by the different flight configurations required during operations and also by the wide variation in exposures during a working day, as there are days with many operations and others with none [1]. Also the flight pattern of Public Safety aviation is very different from that performed by business aviation, as the former constantly operate in low-speed and low-altitude situations - known as "Dead Man's Curve", hovering off-ground flights with a live load hanging, rappelling operations, landings in restricted areas, flights at different speeds, in addition to operating at high altitudes close to maximum take-off weight or open doors [2]. While this specific flight patterns directly influence the sound pressure levels to which crews and patients are exposed, the model of the operated aircraft is also of great relevance.

The Public Air Units of the state of Santa Catarina, in charge of this type of flight operation, operate a fleet of nine rotary-wing aircraft: 8 Eurocopter/Helibras AS 350 B2 Squirrel and one Agusta Westland AW119 MkII. Due to its great versatility, there is a prevalence in the use of the AS 350 B2 aircraft. As it does not have a large internal space and in order not to sacrifice the seat of the second pilot, the approved aeromedical kit is not used and the patient is carried on a stretcher in a transverse position on the rear seat. In doing so, and depending on the patient's height, the rear side door must remain open for the entire flight and thus the entire crew is subjected to high sound pressure levels during flight operations. While the AW 119 MkII aircraft has greater internal space and does not need to fly with the door open when transporting patients, it is a newer aircraft, introduced only in 2000 and with just over 300 units produced, and there is no published data on its acoustical charac-

teristics, especially during rescue and transport operations of patients. Nevertheless, the AW 119 model is already used in several states, such as Rio Grande do Sul and Goiás where, since 2010, and also by the Federal Highway Police - PRF since 2018. Being the AS 350 B2 and the AW 119 MkII different aircraft, noise characteristics are different too depending mainly on the number of main rotor blades and gear ratios in the gear box [3, 4].

Taking this into account, the objective of the present work is to report on data obtained in a survey of the internal acoustic characteristics of these aircraft in the most diverse flight configurations used in public safety operations.

2. METHOD

To reflect the acoustic conditions in the AS350 B2 and AW119 MkII under different flight conditions, calibrated interior noise recordings were made in four different AS350 B2 aircraft and one AW119 MkII in all conditions of interest. Recordings in one AS350 B2 (ARCANJO-01, Eurocopter, 2003, PR-HGR) were carried out twice, in another AS350 B2 (ARCANJO-03, Helibras, 2016, PR-BNU) four times, in a AW119 Mk II aircraft (Águia-02, 2009, PR-PMM) three times and in two other AS350 B2 once each (ÁGUIA-01, Helibras, 2002, PR-HTA and ÁGUIA-07, Eurocopter, 2001, PR-HGH). Information about measurements and aircraft is resumed in Table 1. Initially, in-flight experiments used two microphones in the cabin, one in the central position of the rear seat (passengers) and the other between the two front seats (pilot and co-pilot) in both aircraft models, at the height of the pilot's head. Differences between the levels measured at the front and rear microphones were <1 dB in AS350 B2 and <2 dB in the AW119 MkII. Thus, for the remaining measurements a single microphone was installed in the central position of the rear seat. The data acquisition system (head-acoustics Squadriga II standalone portable recorder + analyzer, G.R.A.S. Diffuse Field Microphone Type 40AQ) was calibrated using a Larson Davis CAL200 Acoustic calibrator before each flight. Data acquisition was performed using a sampling rate of 48kHz and 24 bit resolution.

Table 1: Measurements and related aircraft

Measurement Identifier	Date	Flight Conditions	Register	Build	Manufacturer	Model
BNU1	oct/2020	all	PR-BNU	2016	Helibras	AS350 B2
BNU2	jan/2021	all w/o take-off and landing	PR-BNU	2016	Helibras	AS350 B2
BNU3	jun/2021	all	PR-BNU	2016	Helibras	AS350 B2
BNU4	jun/2021	all	PR-BNU	2016	Helibras	AS350 B2
HGR1	may/2018	cruise only	PR-HGR	2003	Eurocopter	AS350 B2
HGR2	aug/2020	all	PR-HGR	2003	Eurocopter	AS350 B2
HTA	nov/2020	all	PR-HTA	2002	Helibras	AS350 B2
HGH	feb/2021	all	PR-HGH	2001	Eurocopter	AS350 B2
PMM1	fev/2021	all	PR-PMM	2009	Agusta	AW119 MkII
PMM2	mar/2021	all	PR-PMM	2009	Agusta	AW119 MkII
PMM3	mar/2021	all	PR-PMM	2009	Agusta	AW119 MkII

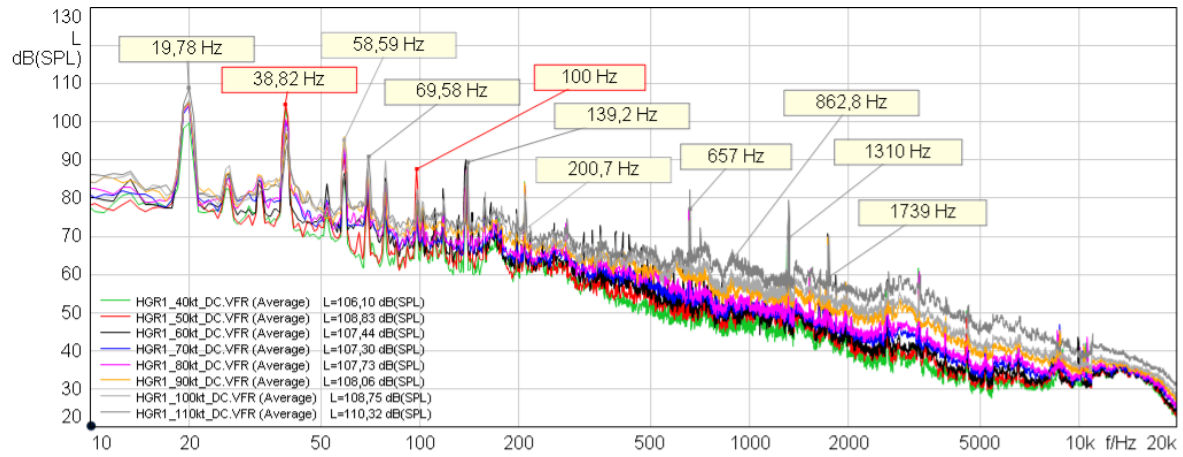
Specifically, data acquisition was realized in all flight configurations that are typically flown with the AS 350B2 and AW119 MKII in Public Safety missions, including flying both with the rear door open and closed. To simulate low loading and unloading operations with the aircraft powered on, measurements were carried out inside the cabin while hovering at low altitudes (In Ground Effect - IGE). To simulate rappelling operations, measurements inside the aircraft were made during hovering Out of Ground Effect (OGE) at 500ft above ground level (AGL) for the AS350 B2 and at 800ft AGL for the AW119 MkII. To simulate the operations with external loads, such as bambi bucket, rescue triangle, stretcher, sling and rescue basket, measurements were made during flights with the rear door open at different speeds, including sharp turns (360 degrees left with 60kt and 15 degrees bank angle). Finally, in order to characterize the noise during the transport of patients, measurements were made during take off ($v_y=55kt$ for the AS350 B2 and $v_y=60kt$ for the AW119 MkII, both until 300ft AGL), different cruising speeds, landing and taxi operations, both all doors closed as well with the left rear door open in AS350 B2 and both rear doors open in AW119 MkII.

During aerial operations, low speeds (40 to 60 kt), are associated with operations with the left rear door open such as sling, bambi bucket, res-

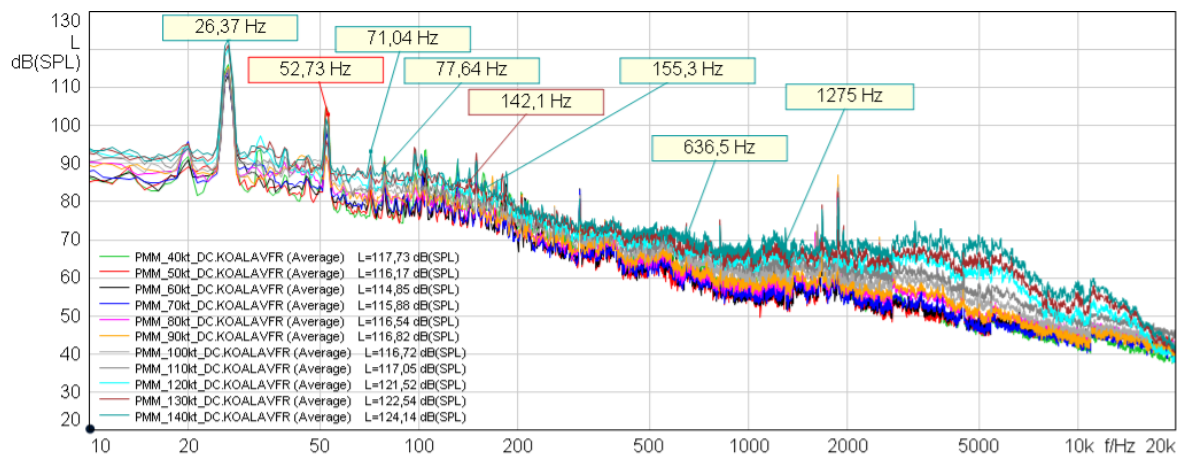
cue triangle, rescue basket, stretcher, external cargo operations and rescue hoist. On the other hand, higher speeds (over 70kt), are usually associated with point-to-point travel with all doors closed, e.g. transporting the patient to the hospital. In the AS350 B2 these transports are eventually realized with one rear door open if no aeromedical kit is installed and the patient is transported transversal and taller than 1,65m. As the AW119 MKII features greater internal space and a specific internal place for the stretcher, there is no operational need to fly with its rear door open to accommodate the patients. But, for operational reasons, when it was necessary to open the rear doors of the AW119 MKII aircraft, both doors were opened, for flight speed not exceeding 85 kt due to operational limitations.

IGE, Taxi and OGE operations are usually linked to the loading and unloading of personnel in the hot zones¹ and rappelling, respectively. In turn, sharp turns are usually linked to wild fire operations and aerial policing. In all these cases, as well as for landing and take offs in restricted areas, the left rear door of the AS350 or both left and right rear doors in AW119 aircraft are open. Data analyses were performed using head-acoustics ArtemiS Suite v12 software using 1/n-octave, FFT analysis, and variable frequency resolution FFT for better low frequency analysis.

¹Area that is considered to be dangerous.



(a) AS350 B2, PR-HGR1



(b) AW 119 MkII, PR-PR-PMM2

Figure 1: Spectrum in terms of sound pressure levels measured in the AS350 B2 helicopter and AW119 MKII helicopter cabins during cruise flight at different speeds and with all doors closed. Spectrum obtained with the VFR-FFT analysis (FFT length 4096 samples, Hanning window, 50% overlap, high VFR Bandwidth).

3. RESULTS AND DISCUSSION

In this section, data analyses and discussion of the results will be presented, as well as a small explanation about the operation and functioning of the aircraft.

3.1 Interior sound pressure levels as a function of frequency

General spectral noise characteristics during flight were analyzed by means of a VFR-FFT analysis (FFT length 4096 samples, Hanning Window, 50 % overlap, high VFR Bandwidth) and are shown in Figure 1 for the AS350 B2 and AW119 MkII.

For the AS350 B2, tonal components are found at the main rotor's BPF and its harmonics, e.g.

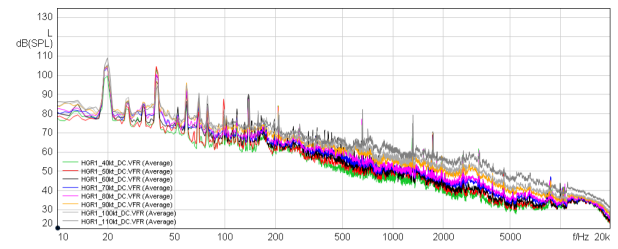
19.8 Hz, 38.8 Hz, 58.6 Hz, and so on, and for the AW119 MKII, at 26.1 Hz, 52.2 Hz, 78.3 Hz, and so on, regardless of cruise speed.² The BPF of the main rotor of these helicopters are therefore at the lower limit of the frequency range of human hearing, and thus all analyses were carried out starting at 10 Hz. In addition, the BPF of the tail rotor blades can be noted, being $2 \cdot 2086 \text{ rpm} / 60 \text{ s} = 69.6 \text{ Hz}$ and its multiples for the AS350 B2 and $2 \cdot 2126 \text{ rpm} / 60 \text{ s} = 70.8 \text{ Hz}$

²The increase in cruise speed of a helicopter is not due to an increase in the rotational frequency of the main rotor, as this is controlled to remain within a small range (385 to 394 rpm for the AS350 B2 and between 388 and 395 rpm for the AW119 MKII). BPF in these helicopters are given by multiplication of the rotation frequency of 390 rpm (AS350 B2) and 392 rpm (AW119 MKII) and the number of blades, which is 3 for AS350 B2 and 4 for AW119 MKII.

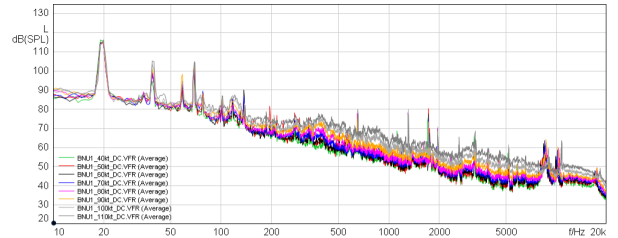
and it multiplies for the AW 119 MKII. As with the main rotor, the rotation of the tail rotor does not vary with the speed of the helicopter. It is also possible to identify, in both aircraft models (AS350B2 and AW119MKII), the distinctive frequencies from the turbine (863 Hz and 635 Hz) and turbine shaft (100 Hz and 75 Hz) and its harmonics. Sound pressure level spectra obtained in different AS 350 B2 and one AW 119 Mk II aircraft during cruise flight (DC and DO) were calculated with the same VFR-FFT analyses and presented in Figures 2 and 3. As expected the pattern of tonal components related to the main rotor's and tail rotor's BPFs are consistent in all AS 350 B2 aircraft. As only one AW119 aircraft was tested, there is no way to confirm the pattern for this aircraft.

Analyzing the $L_{eq}(f)$ at the main rotors BPFs and its first and second harmonics during cruise flight with different speeds in different AS 350 B2 aircraft and closed doors (Figure 2), no absolutely consistent pattern regarding an expected reduction of the SPLs associated to increasing orders of BPF harmonics is found. Analyzing the data for the AS350 B2 aircraft flown with the left rear door open a slightly consistent pattern of SPL reduction with increasing BPF order is found (Figure 3). On the other hand, in the AW119 MkII there is a consistent pattern of SPL reduction with increasing BPF order, with doors open or closed as seen in Figures 2e) and 3 e).

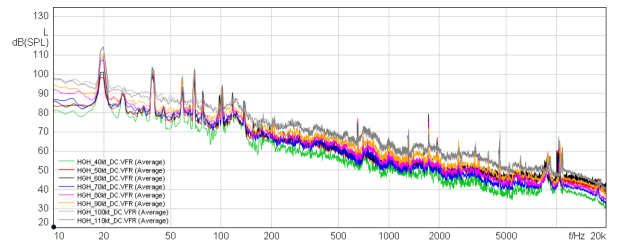
When flying with the doors open spectra are similar in the whole frequency range, which is in line with a generally smaller standard deviation of unweighted SPLs measured with the rear doors open when compared to the same flight condition but all doors closed (Table 2 and 3). Sound pressure level spectra for flight conditions other than cruise flight, i.e. IGE, taxi, take-off, OGE, sharp turns (360°left, 60kt and 15°bank angle) and landing, for AS350 B2 (BNU2, HGR2, HTA and HGH) are given in Figures 4 and 6 and for the AW119 MkII (PMM1, PMM2 and PMM3) in Figures 5 and 7. As already seen in the data for cruise flight (Figures 2 and 3) the contribution of the BPF's SPL to the global SPL increases when aircraft are flown with an open rear door.



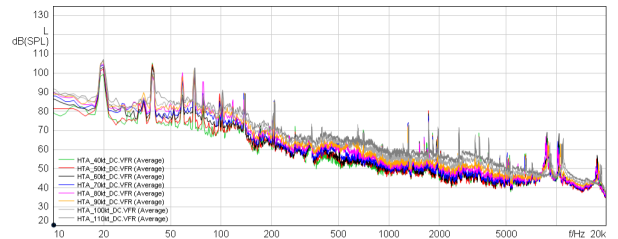
(a) AS350 B2, PR-HGR - all doors closed



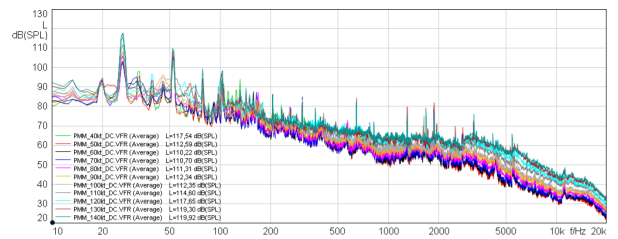
(b) AS350 B2, PR-BNU - all doors closed



(c) AS350 B2, PR-HGH - all doors closed

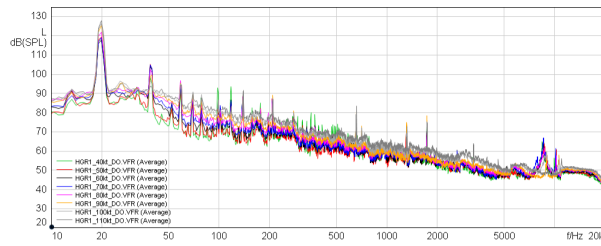


(d) AS350 B2, PR-HTA - all doors closed

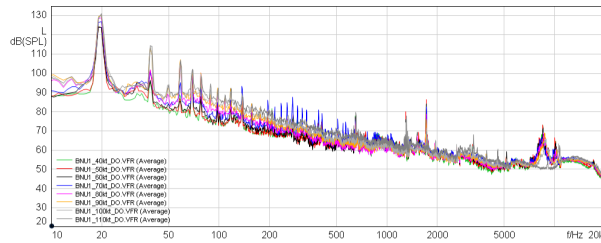


(e) AW 119 MkII, PR-PMM - all doors closed

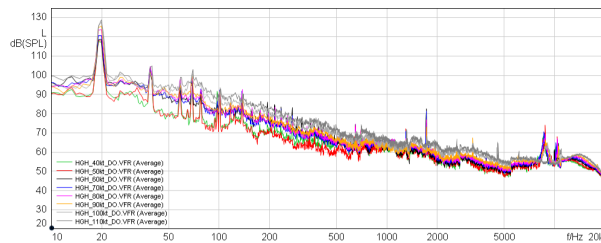
Figure 2: Spectrum (unweighted equivalent SPLs L_{eq}) measured in AS 350 B2 and AW 119 MkII aircraft during cruise flight at different speeds with all doors closed. VFR-FFT analysis (FFT length 4096 samples, Hann window, 50% overlap, high VFR BW)



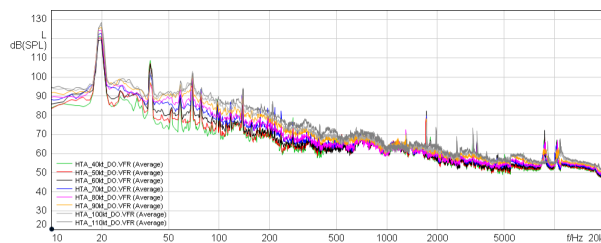
(a) AS350 B2, PR-HGR - left rear door open



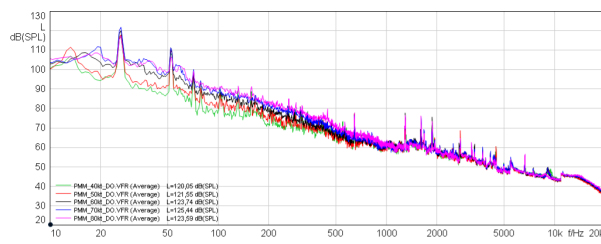
(b) AS350 B2, PR-BNU - left rear door open



(c) AS350 B2, PR-HGH - left rear door open

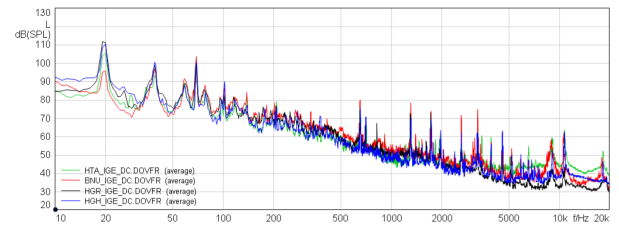


(d) AS350 B2, PR-HTA - left rear door open

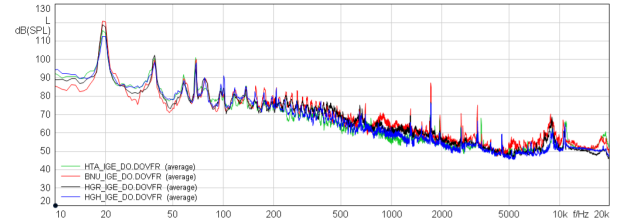


(e) AW119 MkII, PR-PMM - both rear doors open

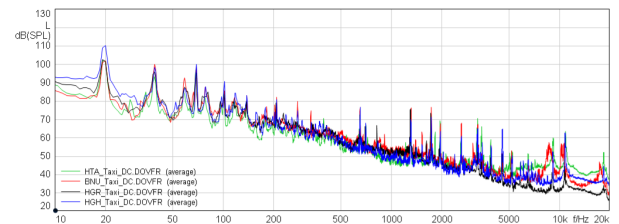
Figure 3: Spectrum (unweighted equivalent SPLs L_{eq}) measured in AS 350 B2 and AW 119 MkII aircraft during cruise flight at different speeds with left rear door open (AS350 B2) and all doors open (AW119 MkII). Spectrum obtained with the VFR-FFT analysis (FFT length 4096 samples, Hanning Window, 50 % overlap, high VFR Bandwidth)



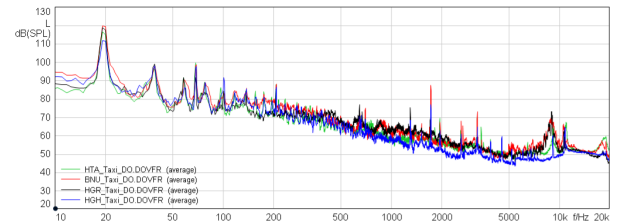
(a) IGE - all doors closed



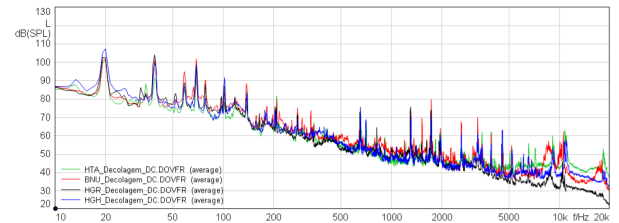
(b) IGE - left rear door open



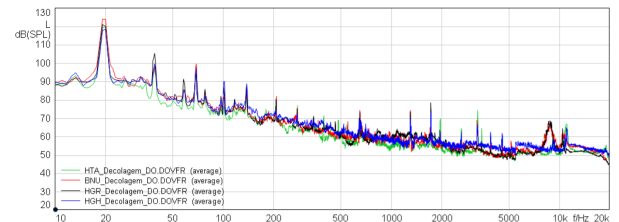
(c) Taxi - all doors closed



(d) Taxi - left rear door open



(e) Takeoff - all doors closed



(f) Takeoff - left rear door open

Figure 4: VFR-FFT spectrum (unweighted equivalent SPL L_{eq}) measured in the AS350 B2 during IGE, taxi and take-off. FFT length 4096 samples, Hanning Window, 50 % overlap, high VFR Bandwidth.

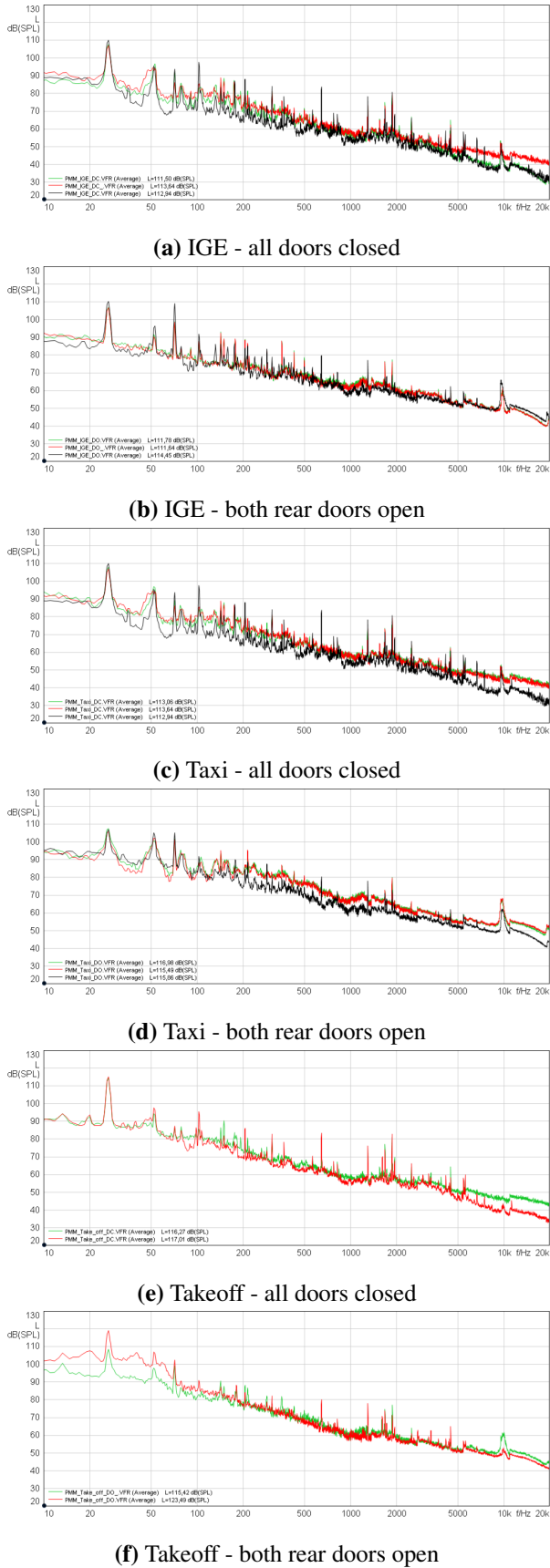


Figure 5: VFR-FFT spectrum (unweighted equivalent SPL L_{eq}) measured in the AW119 MkII during IGE, taxi and take-off. FFT length 4096 samples, Hanning Window, 50 % overlap, high VFR Bandwidth.

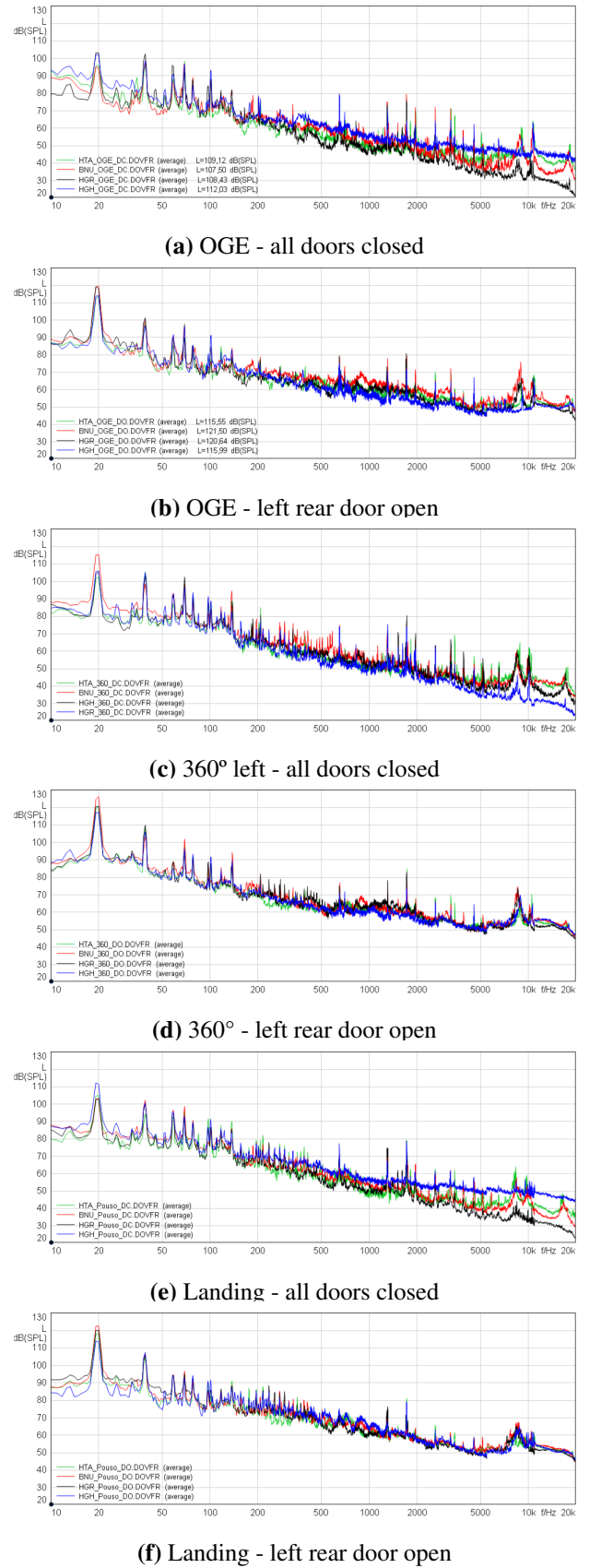


Figure 6: VFR-FFT spectrum (unweighted equivalent SPL L_{eq}) measured in the AS350 B2 during OGE, sharp turns (360 degrees left with 60kt and 15 degrees bank angle), and landing. FFT length 4096 samples, Hanning Window, 50 % overlap, high VFR Bandwidth.

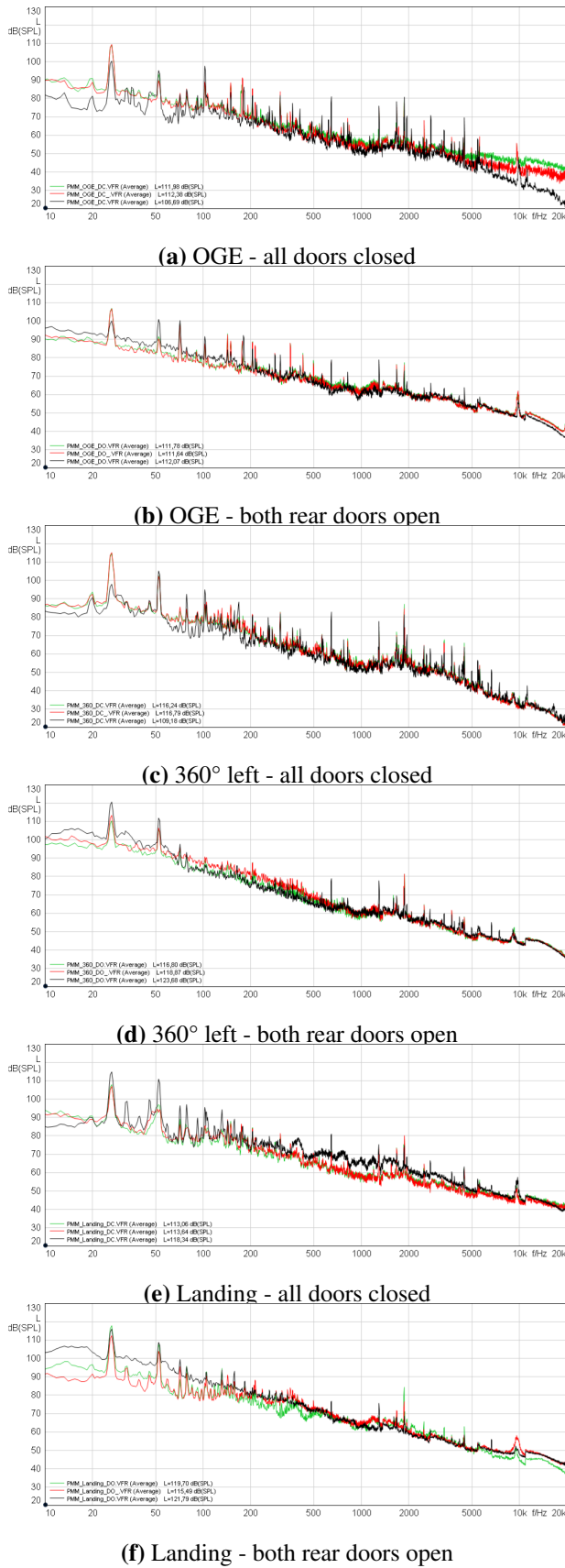


Figure 7: VFR-FFT spectrum (unweighted equivalent SPL L_{eq}) measured in the AW119 MkII during OGE, sharp turns (360 degrees left with 60kt and 15 degrees bank angle), and landing. FFT length 4096 samples, Hanning Window, 50 % overlap, high VFR Bandwidth.

3.2 A-weighted equivalent SPLs for hearing loss risk assessment

For hearing loss risk assessment A-weighted global equivalent SPLs L_{Aeq} are usually considered and are plotted in Figures 8 and 9 for different flight conditions. A-weighted SPL 1/3-octave spectra are given in Figures 10 and 11.

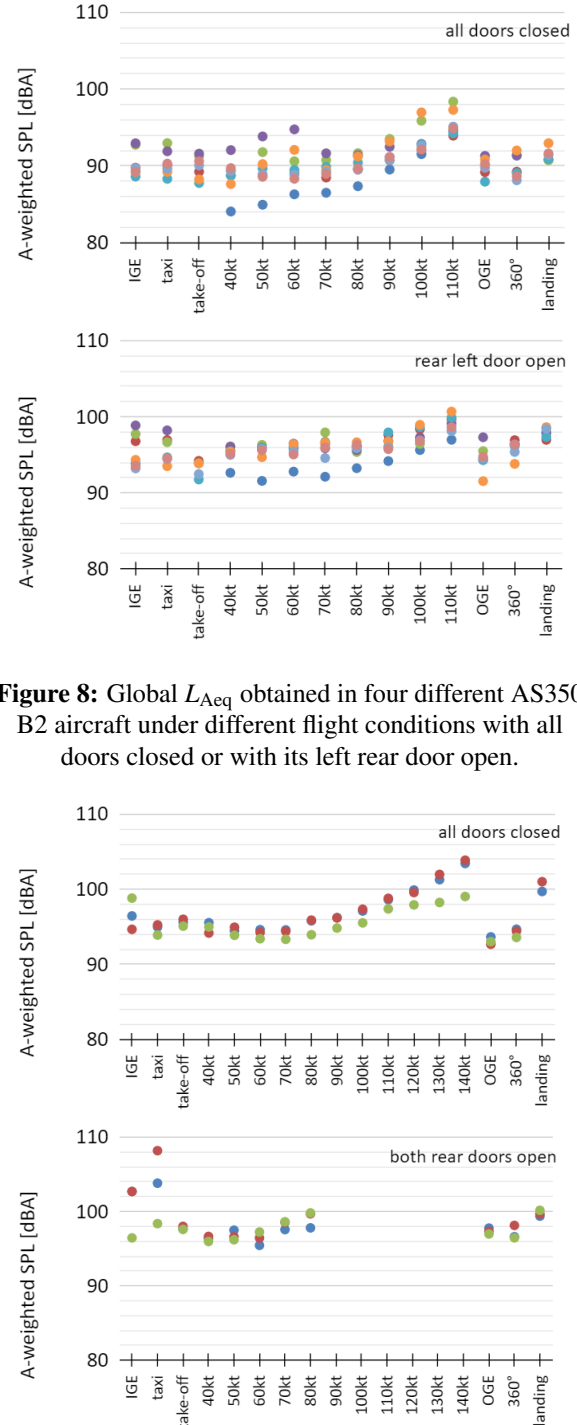
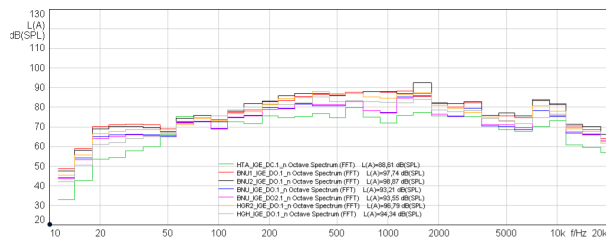
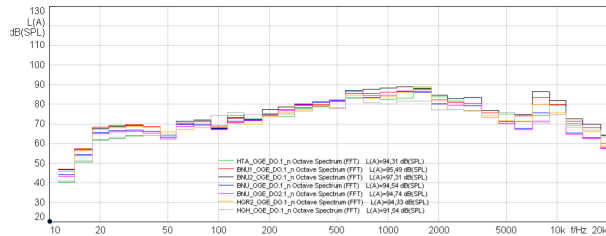


Figure 8: Global L_{Aeq} obtained in four different AS350 B2 aircraft under different flight conditions with all doors closed or with its left rear door open.

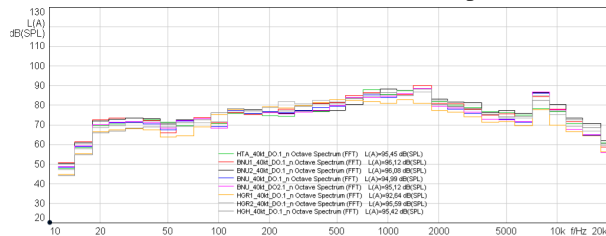
Figure 9: Global L_{Aeq} obtained in an AW119 MKII aircraft under different flight conditions with all doors closed or with its left rear door open.



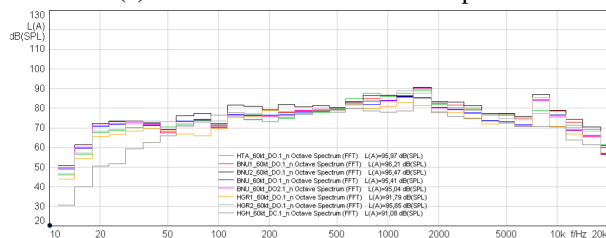
(a) AS350 IGE - left rear door open



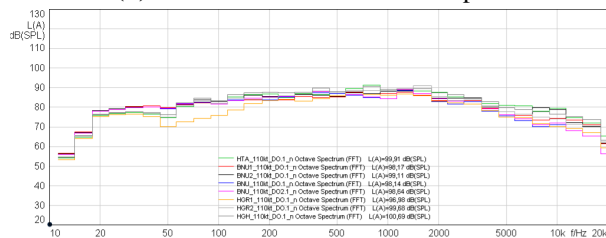
(b) AS350 OGE - left rear door open



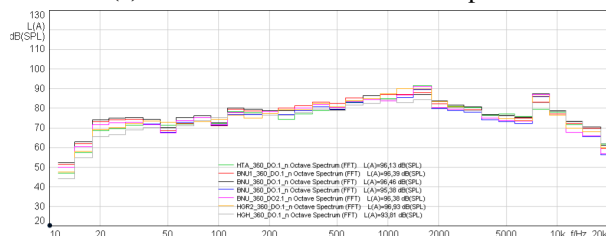
(c) AS350 40kt - left rear door open



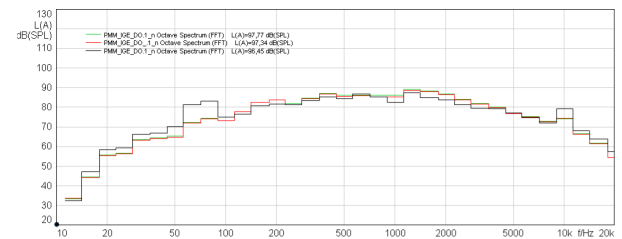
(d) AS350 60kt - left rear door open



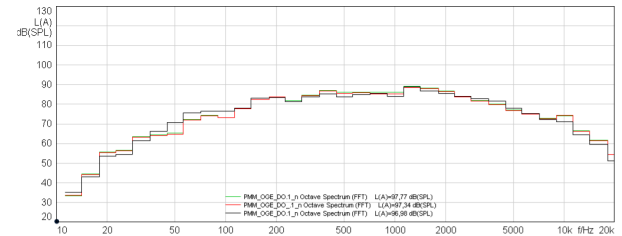
(e) AS350 110kt - left rear door open



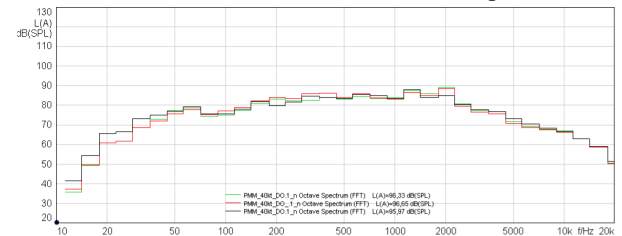
(f) AS350 360° left - left rear door open



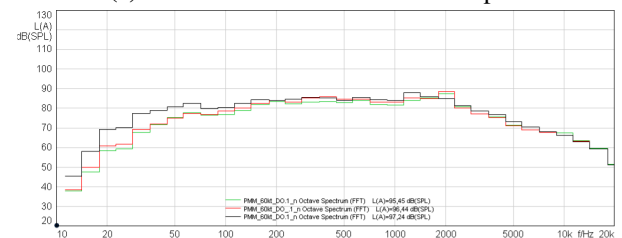
(a) AW119 IGE - both rear doors open



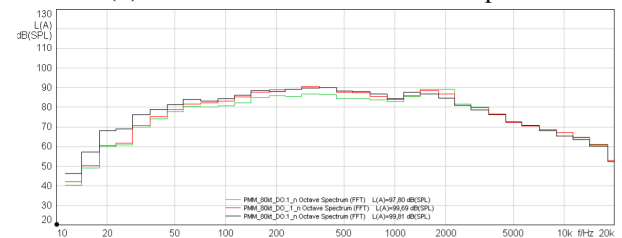
(b) AW119 OGE - both rear doors open



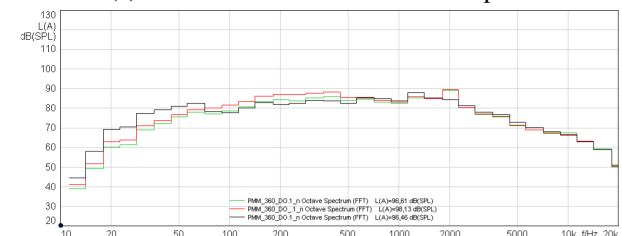
(c) AW119 40kt - both rear doors open



(d) AW119 60kt - both rear doors open



(e) AW119 80kt - both rear doors open



(f) AW119 360° left - both rear doors open

Figure 10: A-weighted 1/3 octave SPL spectrum measured in the AS350B2 aircraft during the most used flight configurations with the left rear door open. FFT length 4096 samples, Hanning Window, 50 % overlap

Figure 11: A-weighted 1/3 octave SPL spectrum in the AW119 MkII aircraft during the most used flight configurations with both rear doors open. FFT length 4096 samples, Hanning Window, 50 % overlap



For the most relevant and critical conditions in the AS 350 B2 (IGE-DO, OGE-DO, cruise with 40 kt, 60 kt and 110 kt [DO], and sharp turns (360 degrees left with 60kt and 15 degrees bank angle, door open)) and for the AW119 MkII (IGE-DO, OGE-DO, cruise with 40 kt, 60 kt and 80 kt [DO], and sharp turns (360 degrees left with 60kt and 15 degrees bank angle, door open)) $L_{Aeq}(i)$ were also calculated in 1/3-octave bands (Figures 10 and 11). It is clearly seen that $L_{Aeq}(i)$ in bands between 200 Hz and 10 kHz are the most relevant for the global L_{Aeq} , for both helicopter models, depending on the operation. An increase in the $L_{Aeq}(i)$ with increasing speed for cruise situations is also clearly seen.

For the critical conditions, mean L_{Aeq} measured in each helicopter model are quite similar for most cases, but landing [DO] and cruising with 110kt [DO] in the AS350 B2 and Taxi [DO] and cruising with 140kt [DC] in the AW119 MkII showed the highest mean L_{Aeq} . Mean L_{Aeq} in AS 350 B2 and AW119 MkII are between 95 and 99 dB when flying with open doors. When flown with doors closed, mean L_{Aeq} in the AW119 MkII is up to 4 dB higher, for cruise speeds.

3.3 Basic statistics of global unweighted and weighted SPLs

Global unweighted and weighted SPLs measured under different flight conditions as well as basic statistics such as mean SPLs, median SPLs and standard deviations are given in Table 2 and 3. Mean and median SPLs are very similar for all cases (unweighted and weighted SPLs), indicating that both mean and median are representative measures of central tendency. Data obtained in the AW119 MkII during hover inside the ground effect (IGE) and Taxi show larger SPL standard deviations. This can be caused by the instability of the downwash's direction, since the air cushion created by the main rotor is greatly influenced by the type and roughness of the ground, winds or small displacements of the aircraft.

In the AS 350 B2 (Table 2) L_{eq} increase up to 4 dB when the aircraft's cruise speed rises from 40 to 110 kt with all doors closed. When flying with the left rear door open L_{eq} increase up to 10 dB when the aircraft's cruise speed rises from 40 to 110 kt.

In other hand, for the AW 119 MkII (Table 3) L_{eq} increases up to 6 dB when the aircraft's cruise speed rises from 40 to 140 kt with all doors closed. When flying with all rear doors open L_{eq} almost did not change when the aircraft's speed rises from 40 to 80 kt.

According to Table 2 it the highest L_{eq} , for the AS350 B2, are measured at 100 and 110 kt cruise speed, a speed that is quite often flown during SAR or medevac missions. In these velocities the mean difference between flying with open or closed doors amount to 16 dB comparing L_{eq} s.

For the AW119 MkII (Table 3) the highest L_{eq} are measured at 130 and 140 kt cruise speed, a speed that is often used when respond and emergency call and the transport critical patients to the hospital. The mean difference between flying with open or closed doors amount to 5 dB comparing L_{eq} for 80 kt cruise speed. In these helicopter model is not allowed to fly with open doors faster than 85kt.

Variation of L_{Aeq} as a function of flight condition is larger for closed doors if compared for flying with the rear door open, for both models. Once again L_{Aeq} are largest for 100 and 110 kt cruise speed in the AS350 B2 and 130 and 140 kt in the AW119 MkII. Nevertheless, mean $\{L_{Aeq, DO}\}$ is only 4 dB larger than mean $\{L_{Aeq, DC}\}$ both for 100 and 110 kt in the AS350 B2, as seen from Table 2. In the AW119 MkII, mean $\{L_{Aeq, DO}\}$ is only 4 dB larger than mean $\{L_{Aeq, DC}\}$ both for 70 and 80 kt, as seen from Table 3. The largest effect of flying with open or closed doors, for both models, is seen for cruise at 70 kt. At this speed the mean $\{L_{Aeq, DO, 70kt}\}$ is 7 dB larger than mean $\{L_{Aeq, DC, 70kt}\}$ for the AS350 B2 and 6 dB larger than mean $\{L_{Aeq, DC, 70kt}\}$ in the AW119 MkII.

4. CONCLUSION

From calibrated noise recordings taken inside AS350 B2 and AW119 MkII aircraft during SAR and medevac missions detailed noise data were obtained. These data can be used to estimate crew and patients noise exposure during such missions as well as to design low interior noise mission profiles, at least for normal weather conditions. It was found that both aircraft models

Table 2: Mean, median, standard deviation, minimum and maximum of unweighted, A-weighted and C-weighted global equivalent SPLs measured in different AS350 B2 aircraft during different operations with all doors closed (DC) and left rear door open (DO). For take off and landing $n = 6$, cruise $n = 8$, other operations $n = 7$.

Operation		L_{eq}					L_{Aeq}					L_{Ceq}				
		mean	med	SD	min	max	mean	med	SD	min	max	mean	med	SD	min	max
		[dB]					[dBA]					[dBC]				
IGE	(DO)	119	118	3	115	123	95	94	2	93	99	113	112	3	110	117
	(DC)	113	113	3	108	117	90	90	2	89	93	108	108	2	106	117
Taxi	(DO)	118	118	3	114	122	96	95	2	94	98	113	112	2	110	116
	(DC)	111	112	4	106	117	90	90	2	88	93	107	108	3	103	112
Take off $v_y=55kt$	(DO)	122	122	2	120	125	93	94	1	92	94	116	116	2	114	119
	(DC)	109	109	3	106	117	90	90	1	88	92	106	106	3	103	112
cruise 40kt	(DO)	122	122	2	119	125	95	95	1	93	96	117	117	2	113	119
	(DC)	109	108	3	106	117	89	89	2	84	92	106	106	3	103	111
cruise 50kt	(DO)	122	122	2	119	125	95	96	2	92	96	117	117	2	114	119
	(DC)	109	108	3	105	116	90	89	3	85	94	106	105	2	104	111
cruise 60kt	(DO)	122	122	2	118	125	96	96	1	93	96	117	117	2	113	119
	(DC)	109	108	3	107	116	90	89	3	86	95	106	105	2	103	111
cruise 70kt	(DO)	124	124	2	119	128	96	96	2	92	98	118	118	2	114	122
	(DC)	109	108	3	107	116	89	89	2	87	92	106	106	2	103	111
cruise 80kt	(DO)	126	126	2	122	130	96	96	1	93	97	121	120	2	119	124
	(DC)	110	110	3	107	116	90	90	1	87	92	107	107	2	104	111
cruise 90kt	(DO)	128	128	2	125	131	96	96	1	94	98	122	123	2	119	125
	(DC)	111	110	3	107	116	92	91	1	90	94	108	107	2	104	111
cruise 100kt	(DO)	129	129	2	126	131	97	97	1	96	99	123	124	2	119	125
	(DC)	112	111	3	108	116	93	93	2	92	97	109	108	2	105	112
cruise 110kt	(DO)	130	130	1	128	131	99	99	1	97	101	124	124	1	122	126
	(DC)	112	111	3	109	117	95	95	2	94	98	110	109	2	105	113
OGE 500ft AGL	(DO)	118	118	3	115	121	95	95	2	92	97	113	113	2	109	115
	(DC)	109	109	4	106	117	90	90	1	88	91	105	105	3	102	111
360 left	(DO)	123	124	3	119	126	96	96	1	94	97	118	119	3	113	121
	(DC)	109	109	2	107	113	90	89	2	88	92	107	107	2	105	111
Landing	(DO)	122	122	4	116	127	98	98	1	97	99	117	117	3	112	121
	(DC)	110	109	3	108	114	91	91	1	91	93	107	107	2	105	109

have similar in-cabin SPLs when flying with open doors. Also, there is a consistent increase in internal L_{Aeq} with increasing speed in both aircraft. For cruise speeds from 40 to 110kt, the AS350 B2 in-cabin L_{Aeq} is up to 6 dB lower than L_{Aeq} in the AW119 MkII. Flying the aircraft with doors closed, compared to operation with open doors, reduces the interior L_{Aeq} up to 6 dB (AS350 B2) and up to 3dB (AW119 MkII) during cruise flight and up to 9 dB (AS350 B2) during landing operations. For the AW119 MkII,

there was no variation in L_{Aeq} during landing operations with open or closed doors. Ample interior space in the AW119 aircraft allows to fly with closed resulting in lower interior SPLs. In the AS350 B2 L_{Aeq} can be reduced up to 8 dB closing the doors of the aircraft, requiring installation of the aeromedic kit.

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Table 3: Mean, median, standard deviation, minimum and maximum of unweighted, A-weighted and C-weighted global equivalent SPLs measured in AW119 MkII aircraft during different operations ($n = 3$) with all doors closed (DC) and both rear doors open (DO) only until 80kt due to the aircraft model's operating restrictions.

Operation		L_{eq}					L_{Aeq}					L_{Ceq}				
		mean	med	SD	min	max	mean	med	SD	min	max	mean	med	SD	min	max
		[dB]					[dBA]					[dBC]				
IGE	(DO)	115	115	1	114	116	101	103	4	96	103	113	113	1	112	113
	(DC)	113	111	3	111	117	97	96	2	95	99	109	107	3	107	112
Taxi	(DO)	115	115	1	115	116	103	104	5	98	104	113	113	1	112	114
	(DC)	112	112	0	111	112	95	95	1	94	95	108	108	0	108	108
Take off $v_y=60kt$	(DO)	117	115	5	114	123	98	98	0	98	98	114	112	5	111	120
	(DC)	116	116	0	116	116	96	96	0	95	96	112	113	1	112	113
cruise 40kt	(DO)	117	116	2	116	120	96	96	0	96	97	114	113	2	113	116
	(DC)	118	118	0	118	118	95	95	1	94	96	113	114	1	112	114
cruise 50kt	(DO)	119	119	2	118	121	97	97	1	96	97	116	115	1	115	117
	(DC)	114	115	2	112	116	94	94	1	94	95	111	111	1	110	112
cruise 60kt	(DO)	118	116	5	115	123	96	96	1	95	97	115	113	4	112	119
	(DC)	113	115	3	110	115	94	94	1	93	95	110	111	2	108	111
cruise 70kt	(DO)	120	117	5	117	125	98	99	1	98	99	116	114	4	114	121
	(DC)	114	115	3	110	116	94	94	1	93	95	110	111	2	108	112
cruise 80kt	(DO)	119	118	3	111	116	99	100	1	94	96	116	116	3	109	112
	(DC)	114	116	3	117	123	95	96	1	98	100	111	112	2	114	119
cruise 90kt	(DC)	115	116	3	112	116	96	96	1	95	96	111	113	2	109	113
cruise 100kt	(DC)	115	115	2	112	116	97	97	1	96	97	111	112	2	109	113
cruise 110kt	(DC)	116	116	1	114	117	98	99	1	97	99	112	113	1	111	113
cruise 120kt	(DC)	120	120	2	117	121	99	100	1	98	100	116	116	2	114	117
cruise 130kt	(DC)	121	122	2	119	123	100	101	2	98	102	117	118	2	115	119
cruise 140kt	(DC)	123	124	3	120	124	102	103	3	99	104	119	120	2	116	120
OGE 800ft AGL	(DO)	111	111	0	106	111	97	97	0	93	94	108	108	0	104	108
	(DC)	109	111	3	110	111	93	93	0	97	98	106	107	2	108	109
360 left	(DO)	119	118	4	109	117	97	97	1	94	95	116	115	4	107	113
	(DC)	114	116	4	116	123	94	94	1	96	98	111	112	3	113	120
Landing	(DO)	118	119	3	115	116	100	100	0	100	101	115	116	3	114	115
	(DC)	116	116	1	115	121	100	100	1	99	100	115	115	1	112	116

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