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Sound Pressure Levels inside the cabin of the rotary and fixed-wings of Santa Catarina State during aeromedical transfers

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Abstract

The need to transfer patients has the main purpose of taking the patient to a location that has superior resources that do not are available at the place of origin. Due to the lack of information related to the sound pressure levels of rotary-wing aircraft, all pediatric aeromedical transports performed by the Aerial Operations Battalion are carried out by fixed-wing aircraft. When transportation is not possible with the airplane, this is mandatory carried out by ambulance. To provide criteria for a technical decision whether to use aircraft or ambulances for pediatric aeromedical transports noise measurements were carried out in the interior of AS350 B2 and AW 119MkII helicopters and Cessna 210N, Cessna 206H and Embraer EMB-820C airplanes. Aircraft were equipped with recording equipment (microphone and SQuadriga II) and flew with cruise speeds. Mean LpAeq in AS350 aircraft (n=6) were 93dBA@100kt and 95dBA@110kt (doors closed [DC]), 97dBA@100kt and 99 dBA@110kt (left rear door open [DO]). LpAeq standard deviation was 2dB@100kt and 1dB@110kt [DC] and 1dB in both speeds/DO. Mean LpCeq was 109dBC@100kt[DC], 110dBC@110kt[DC] and 123dBC@100kt and 124dBC@110kt (left rear door open). LpCeq standard deviations were 2dB in both speeds [DC], 2dB@100kt and 1dB@110kt [DO]. Mean LpAeq in AW119MKII aircraft (n=3) were 100dBA@130kt and 102dBA@140kt. LpAeq standard deviation was 2dB in 130kt and 3 dB at 140kt. Mean LpCeq were 117dBC@130kt and 119dBC@140kt [DC] and the LpCeq standard deviation was 2db for both speeds. In the C-210N (n=5) mean LpAeq were 91 dBA@140kt with 1dB of standard deviation. Mean LpCeq were 104dBC@140kt with 0dB standard deviation. In the C-206H (n=7) mean LpAeq were 92 dBA@115kt with 0dB standard deviation. Mean LpCeq were 107dBC@115kt with 1dB standard deviation. In the BE-55 (n=15) mean LpAeq were 89 dBA@130kt with 1dB standard deviation. Mean LpCeq were 104dBC@130kt with 1dB standard deviation. In the EMB-820C (n=13) mean LpAeq were 96 dBA@200kt with 1dB standard deviation. Mean LpCeq were 103dBC@200kt with 1dB standard deviation. LpAeq measured on the AS350 were 3 to 4 dBA higher and 7 to 8 dBA [DO] also higher than planes. Measured LpAeq in AW119 were 8 to 9 dBA higer. The data can be used by the operators to build or change protocols involving patients transportation, especially newborns. *resumo* in Portuguese contributions).

Keywords: acoustics, helicopter, airplane, aircraft, noise, aeromedical, transfer.

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1. INTRODUCTION

The transfer of patients is very often employed to provide medical assistance at place that has superior resources that do not are available at the place of origin or to enable the patient to receive treatment in a hospital of choice [1]. To this end, every patient must be transported to the most appropriate referral, using the most appropriate model of transport, whether land or air [2]. In order to choose the correct mode of transport, several factors must be taken into account, including the clinical condition of the patient, the distance to be covered, weather conditions, the number and type of employees needed, the equipment required for stabilization of the patient and availability at the time of transport [3]. In general, both ambulances are used, as well as rotary-wings and fixed-wings.

Airplanes are ideal for long distance transportation due to their speed, low vibration and noise, adequate lighting and space for monitoring and patient handling. However, it transportation by airplanes comes at a high operating cost, is not suitable for urban transport and needs the help of an ambulance or rotary-wings to transport the patient to the airport and vice versa. On the other hand, rotary-wings are considered more efficient to transport critically ill patients within a radius of 160 to 240 km, but they have some disadvantages, such as limited internal space and generally higher noise levels [4], which substantially interfere with neonatal transport [3].

According to the records of the Aerial Operations Battalion of the Military Fire Brigade of Santa Catarina (BOA/CBMSC), since the beginning of activities in 2010 until 10th of June of 2022, about 1767 aeromedical transports have been carried out, as shown in Table 1.

Table 1: Number of aeromedical transfers carried out by the BOA/CBMSC by the years [5].

Year	Aeromedical Transfers
2010	43
2011	82
2012	99
2013	88
2014	73
2015	133
2016	207
2017	56
2018	184
2019	156
2020	157
2021	246
2022	143*
TOTAL	1767
by rotary-wings	1070 (60%)
by fixed-wings	698 (40%)

* until jun/2022.

During these 12 years of operations, almost 40% (698) of the aeromedical transports were carried out by fixed-wings and 60% (1070) were carried out by rotary-wings.

Due to the lack of information related to the sound pressure and vibration levels of rotary-wing aircraft, especially in the models used in Santa Catarina (AS350 B2 and AW 119 MkII), all pediatric aeromedical transport carried out by the Aerial Operations Battalion of the Santa Catarina Military Fire Fighters are carried out using fixed-wing aircraft. When transportation by fixed-wing aircraft is not possible, transportation is carried out, necessarily, by an ambulance (ground transportation).

To date, the main problem in choosing the most suitable type of transportation is the lack of information on the sound pressure level inside the cabins, whether in rotary wing aircraft or in fixed-wing aircraft used by Santa Catarina State. Therefore, the present work reports on the findings of an investigation into the noise inside the cabins of rotary and fixed-wing aircraft used for patient transportation and will help to find the best choice for each transportation need.

Table 2: Aircraft and measurement information

Aircraft Identifier	Number of Measurements	Build	Manufacturer	Model
PR-BNU	Take-off=3 DC and 2 DO, Cruise=4, Landing=2 DC and 3 DO	2016	Helibras	AS350 B2
PR-HGR	Take-off=1, Cruise=2, Landing=1	2003	Eurocopter	AS350 B2
PR-HTA	Take-off=1, Cruise=1, Landing=1	2002	Helibras	AS350 B2
PR-HGH	Take-off=1, Cruise=1, Landing=1	2001	Eurocopter	AS350 B2
PR-PMM	Take-off=3, Cruise=3, Landing=2 DC and 3 DO	2009	Agusta	AW119 MkII
PR-EPH	Take-off=1, Cruise=5, Landing=1	1981	Cessna	C210N
PP-IMA	Take-off=1, Cruise=7, Landing=1	2001	Cessna	C206H
PT-JLE	Take-off=6, Cruise=15, Landing=3	1973	Beechcraft	BE-55
PT-RFT	Take-off=1, Cruise=13, Landing=1	1983	Embraer	EMB-820C

2. METHOD

To obtain data that reflect the acoustic conditions in AS350 B2 and AW119 MkII rotary-wings as well as C210N Centurion, C206H Station Air, BE-55 Baron and EMB-820C Carajá fixed-wing aircraft, in different flight conditions during aeromedical transports, calibrated interior noise recordings were made in four different AS350 B2 aircraft, one AW119 MkII, one C210N, one C206H, one BE-55 and one EMB-820C in all conditions of interest. Recordings in one Eurocopter AS350 B2 (PR-HGR) were carried out twice, in another Helibras AS350 B2 (PR-BNU) four times, in an Agusta Westland AW119 MkII (PR-PMM) three times, in the Cessna 210N (PR-EPH) five times, in the Cessna 206H (PR-IMA) seven times, in the Embraer EMB-820C (PT-RFT) thirteen times, in the Beechcraft BE-55 Baron (PT-JLE) fifteen times, and in yet another Helibras AS350 B2 (PR-HTA) and Eurocopter AS350 B2 (PR-HGH) only once in each aircraft. Information about measurements and aircraft is resumed in Table 2.

Data acquisition was made using a head-acoustics SQuadriga II stand-alone portable recorder/analyzer and a G.R.A.S. Diffuse Field Microphone Type 40AQ, that was calibrated using a Larson Davis CAL200 Acoustic calibrator before each flight. Data acquisition was performed using a sampling rate of 48kHz with 24 bit resolution. Recordings were realized in all

flight configurations that are typically flown in aeromedical transfers, including take-offs, cruise and landing.

Data analyses were performed using head-acoustics ArtemiS Suite v12 software using 1/n-octave, FFT analysis, and variable frequency resolution Fourier analysis for better low frequency analysis. Flight profiles were obtained from an operational management system (Followair®) and the statistical data during aeromedical transfers such as the number of flights and duration were obtained analyzing twelve years of statistical data of BOA/CBMSC flight operations.

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 Analysis of flight profiles

Descriptive statistics for total flight time during aeromedical transport missions carried out by BOA/SC is given in terms of 1st quartile, median, 3rd quartile and interquartile range in Figure 1. It is seen that distributions are reasonably symmetric, with the presence of a considerable number of outliers at the upper end.

The average flight time of aeromedical transfers using BOA/CBMSC rotary-wings is 27 minutes,



Table 3: Statistics of total flight time (FT) of aeromedical transfers realized by BOA/CBMSC aircraft between 2010 and june 2022, in minutes.

Type	1st Quartile	Median	3rd Quartile	Mean	Std. Dev.
Rotary-wings	18	24	33	27	14
Fixed-wings	60	87	123	94	47
Global	21	33	75	54	45

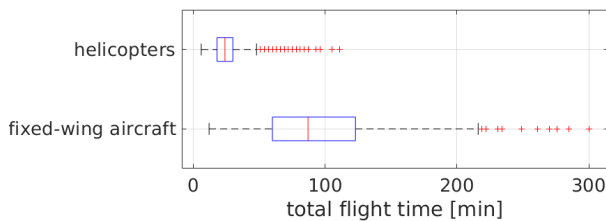


Figure 1: Box-plot of total flight time during aeromedical transport missions carried out by BOA/SC between 2010 and 2022, $n_{\text{rotary-wings}} = 1070$; $n_{\text{fixed-wing aircraft}} = 698$

while mean flight time in BOA/CBMSC fixed-wing aircraft is 94 min, or 1h34min. Statistical data, including standard deviations and quartiles are shown in Table 3.

While for commercial flights [6], 57% of the total flight time is cruise flight, in aeromedical transportation this is likely to be different as air traffic regulations give landing and take-off priority to aircraft in search and rescue operations or transporting seriously ill patients compared to other general aviation aircraft.

The the flight level of the airplanes during aeromedical transfers in Santa Catarina is lower than the commercial aircraft. The total flight time in aeromedical transfers is shorter than other aircraft and the time in which the aircraft is taxiing, landing or taking off is also shorter. This is even more true for rotary-wings, that are subject to different air traffic rules. Thus, for rescue helicopters, the time spent on ground, during take-off and boarding procedures is even shorter than that spent on ground by air medical transport airplanes, as shown in Figure 3.

From the records of the operational management system (Followair) of the BOA/CBMSC [7], the average time spent on taxi, take-off/climb and descent/landing procedures is up to 26% of the total flight time for rotary-wings and is up to

48% for fixed-wings. This means that on average more than 50 or 70% of the total flight time the aircraft are in cruise flight.

For aeromedical transportation it is therefore reasonable to analyze especially the cruise flight situations, that may occur with different speeds depending on the aircraft. While fixed-wing aircraft have a single cruise speed, as shown in Table 4, rotary-wings are often flown with speeds between 100 and 110 kt [DC and DO] for the AS350 B2 and between 130 and 140 kt for the AW119 MkII [DC]. During the transfer missions, the health condition of the patient is important to determinate the flight level, the flight speed and other flight conditions. For example, during the transfer of a poly-traumatized patient, if transferred by an AS350 B2 with no aeromedical kit installed, it will be necessary to fly with the left rear door open and lower speeds to avoid the impact of the wind on the patient's lower limbs.

Table 4: Cruise speeds of fixed-wing aircraft

Aircraft	Cruise speed		
C210N	140 kt	260 km/h	Mach 0.21
C206H	115 kt	213 km/h	Mach 0.18
BE-55	130 kt	240 km/h	Mach 0.20
EMB-820C	200 kt	370 km/h	Mach 0.30

3.2 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).

Figures 4 and 5 show the spectrum, in terms of unweighted sound pressure levels (SPL), of the noise recorded in the cabins of all aircraft (rotary-wings and fixed-wings), for different

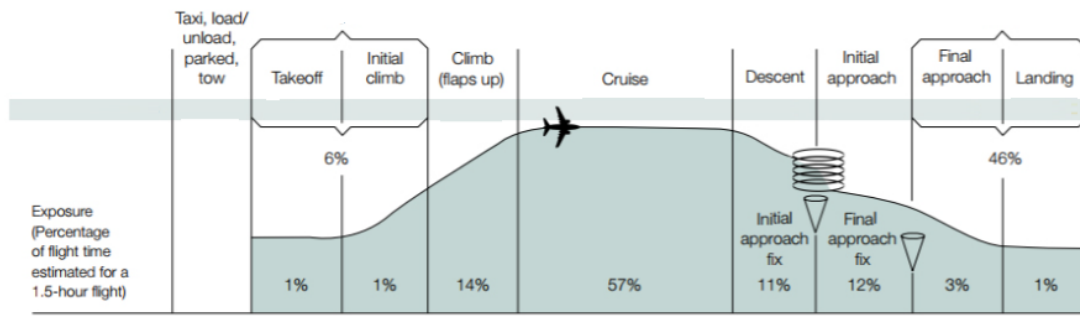
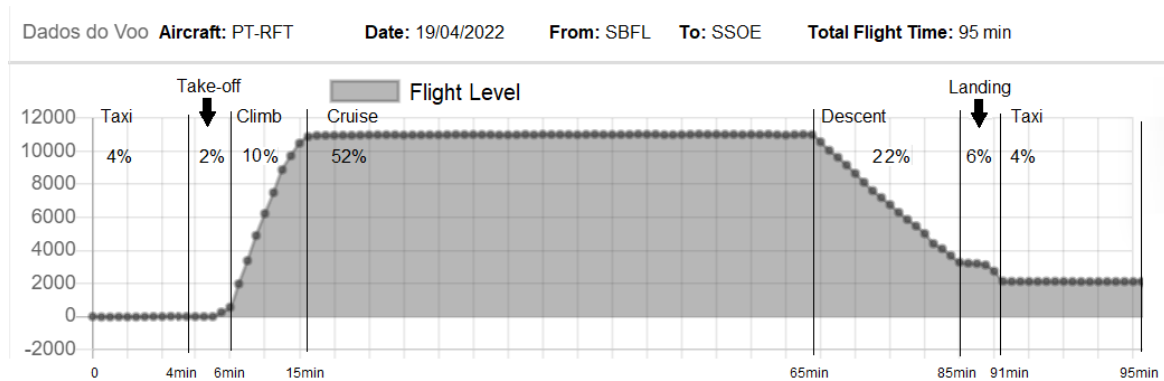
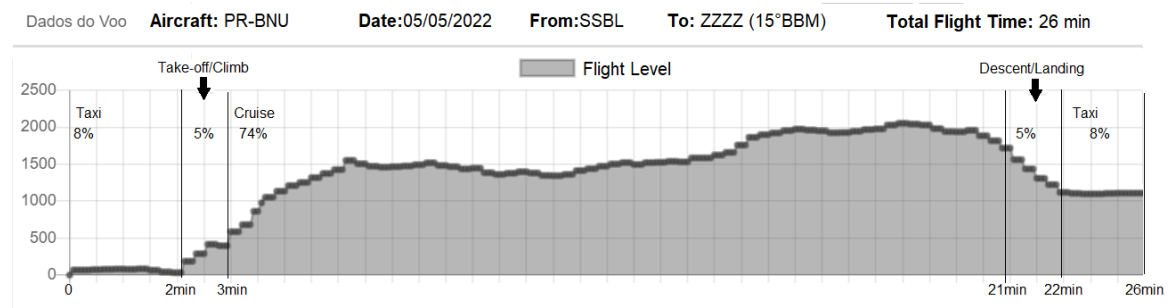


Figure 2: Flight time based on the percentage of commercial airplanes flight time estimated for a 1.5-hour-flight [6].



(a) Example of the flight profile of rotary-wing during transfers



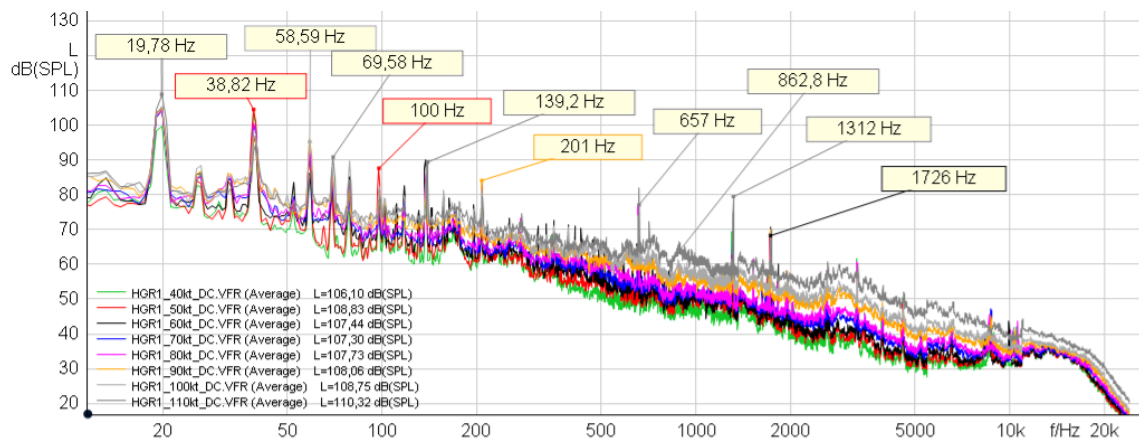
(b) Example of the flight profile of fixed-wing during transfers

Figure 3: Typical flight profiles during aeromedical transfers based on the percentage of BOA/CBMSC aircraft [7]. For airplanes, take-off can be considered from the run until reaching approximately 400 feet when the flaps are retracted and the climb begins. For helicopters, usually, the take-off and climbing phase can not be separated from each other and can be considered beginning with the Vertical take-off until reaching approximately 500 feet, when the cruise flight begins.

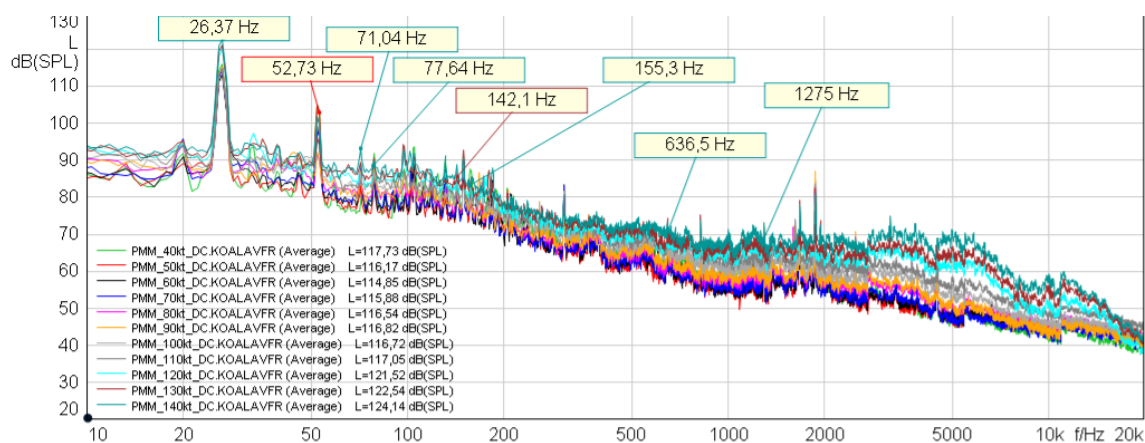
cruise speeds. For rotary-wings, Figure 4 shows the spectrum for different speeds with all doors closed. For fixed wing aircraft, Figure 5 shows the noise spectra for standard cruise speeds for each aircraft as given in Table 4.

For the rotary-wings, tonal components are found, for the AS350 B2, at the main rotor's BPF and its harmonics, e.g. 19.8 Hz, 38.8 Hz,

and so on, and for the AW119 MkII, at 26.1 Hz, 52.2 Hz, and so on, regardless of cruise speed. In addition, the BPF of the tail rotor can be noted at 69.6 Hz and its multiples for the AS350 B2 and 70.8 Hz and its multiples for the AW119 MkII. It is also possible to identify, in both helicopter models, the distinctive frequencies from the turbine (862.8 Hz and 635.3 Hz) and turbine shaft



(a) AS350 B2 (PR-HGR)



(b) AW119 MkII (PR-PPM)

Figure 4: VFR-FFT L_{eq} spectrum measured in the cabin of the AS350 B2 and AW119 Mk II aircraft during cruise flights at different speeds with all doors closed. FFT length 4096 samples, Hanning Window, 50 % overlap, high VFR Bandwidth).

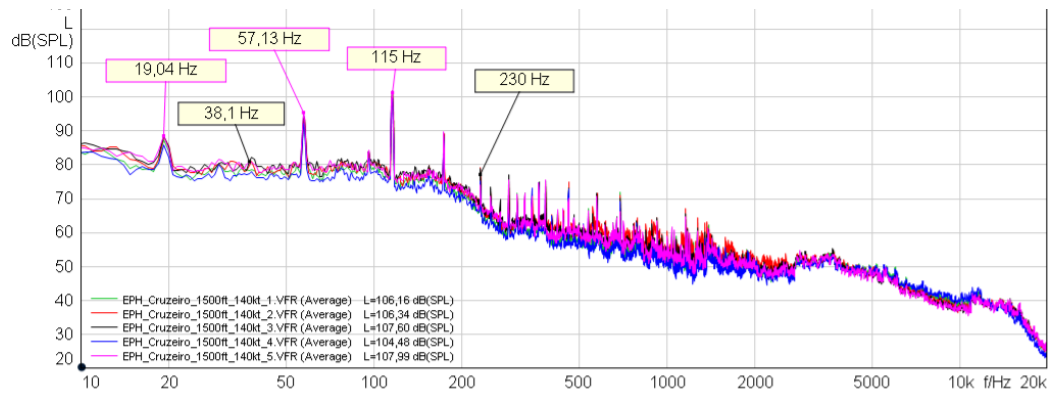
(100 Hz and 75 Hz) and its harmonics¹.

For the fixed-wing airplanes, tonal components are found, for the C210N and C206H, at the propeller's BPF and its harmonics, e.g. 115 Hz and its multiples, for the BE-55, 76.1 Hz and its multiples, and for the EMB-820C, at 93 Hz and its multiples, regardless of cruise speed, as seen in Figure 5.

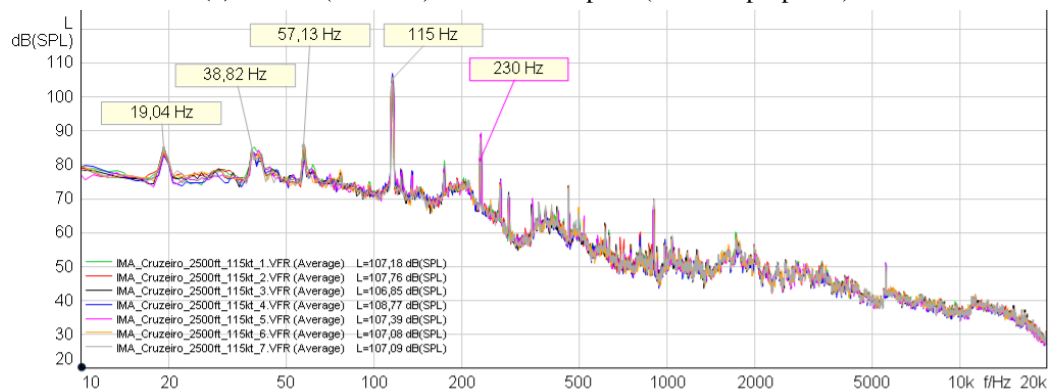
Each model has different engine types and operating regimes. The C210N, C206H have single piston engines, the BE-55 have two piston engines, while the EMB-820C has two turbines. For all these airplanes, the engine will operate with different rotational frequencies depending on flight

configurations, influencing the propeller's BPF. For example, the C210N and C206H engines rotate at 2700 rpm for take-off, 2300 rpm for cruise and around 2500 rpm for climbing and landing, while the BE-55 engine rotates at 2700 rpm for take-off, 2300 rpm during cruise and around 2500 rpm for climbing and landing. The EMB-820C turbine engines use 100% rpm (around 37500 rpm) for take-off, 85% rpm (around 31875 rpm) for cruise, 100% rpm for landings and 91% rpm (around 34125 rpm) for climbing or missed approach. One hundred percent rotation corresponds to 37500 rpm of the turbine and about 2200 propeller's rpm. In both cases, rotary-wings or fixed-wings, the tonal components found in these models are at the lower limit of the frequency range of human hearing, and all analyses were therefore carried out starting at 10 Hz.

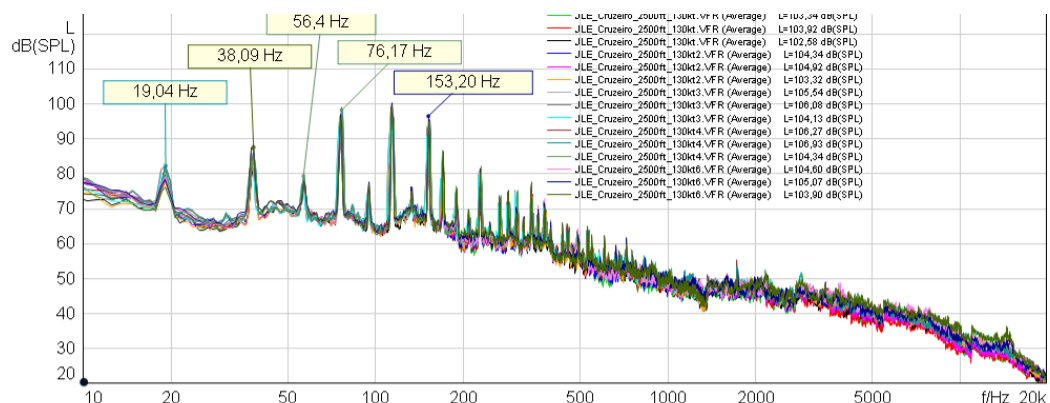
¹Different collective position will cause the increase or decrease in the rotation of the gas-generating turbine, however the device called governor will keep the rotation of the free turbine constant whatever the collective's step, so the main and tail rotor's rpm won't change.



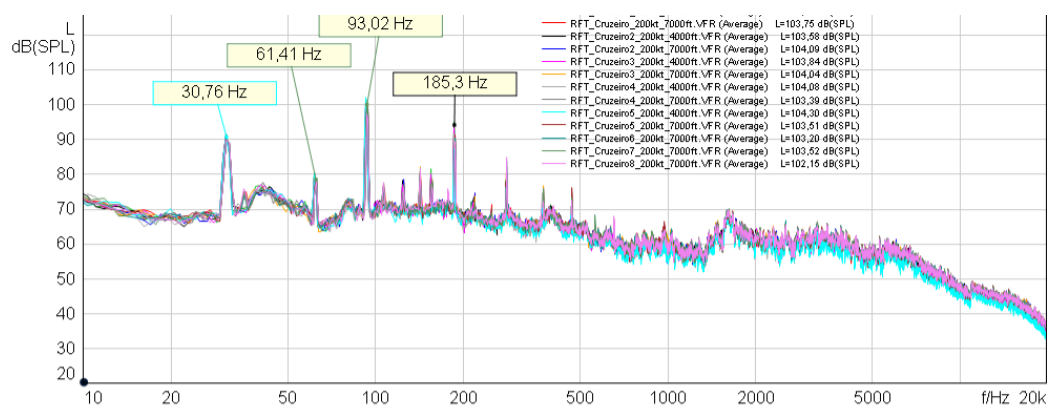
(a) C210N (PR-EPH) 140kt cruise speed (3 blades propeller)



(b) C206H (PP-IMA) 115kt cruise speed (3 blades propeller)



(c) BE-55 (PT-JLE) 130kt cruise speed (2 blades propeller)



(d) EMB-820C (PT-RFT) 200kt cruise speed (3 blades propeller)

Figure 5: VFR-FFT L_{eq} spectrum measured in the cabin of different aircraft during cruise flights at different speeds. FFT length 4096 samples, Hanning Window, 50 % overlap, high VFR Bandwidth.



3.3 Basic statistics of global SPLs

Global unweighted and weighted (A and C) SPLs measured under different flight conditions as well as basic statistics such as mean SPLs, median SPLs and standard deviations are given in Tables 5, 6 and 7. While A-weighted equivalent SPL is the standard measure for hearing loss risk assessment, C-weighted SPL is certainly the more appropriate measure to characterize noise perception in the cabin, as unweighted SPLs are quite elevated for all flight stages in all aircraft.

From Figures 5, 6 and 7 it is seen that even for small numbers of measurements ($N < 10$), mean and median SPLs are very similar for all cases, indicating that both mean and median are representative measures of central tendency. Standard deviations are also small, indicating that the re-

sults of the measurements are quite representative.

For the AS350 B2, L_{eq} increases up to 18 dB comparing operation with closed and open doors. For L_{Aeq} this increase is smaller, 7 dB at maximum. For C-weighted SPLs the difference amounts up to 14 dB. Weighted und unweighted SPLs are affected differently, as flying with open doors increases the contribution of the main rotors fundamental BPF to the overall SPL, as discussed in [4] and increases both low and high frequency noise as can be seen in Figure 6 a) and b) for cruise flight. For the AW119 MkII, operating always with closed doors and at higher cruise speeds, mean interior L_{Aeq} is 102 dBA at 140kt, compared to $\{L_{Aeq, DC}\}=95$ dBA $\{L_{Aeq, DO}\} = 99$ dBA, both at 110kt in the AS350 B2.

Table 5: Mean, median and standard deviation of unweighted, A-weighted and C-weighted global equivalent SPLs measured in the AS350 B2 during different flight stages with all doors closed (DC) and left rear door open (DO).

Aircraft	Flight Stage		L_{eq}			L_{Aeq}			L_{Ceq}		
			mean	med	SD	mean	med	SD	mean	med	SD
			[dB]			[dBA]			[dBC]		
AS350 B2	Take-off	DO ($n = 5$)	122	122	2	93	94	1	116	116	2
		DC ($n = 6$)	109	109	3	90	90	1	106	106	3
	cruise 40kt	DO ($n = 8$)	122	122	2	95	95	1	117	117	2
		DC ($n = 8$)	109	108	3	89	89	2	106	106	3
	cruise 50kt	DO ($n = 8$)	122	122	2	95	96	2	117	117	2
		DC ($n = 8$)	109	108	3	90	89	3	106	105	2
	cruise 60kt	DO ($n = 8$)	122	122	2	96	96	1	117	117	2
		DC ($n = 8$)	109	108	3	90	89	3	106	105	2
	cruise 70kt	DO ($n = 8$)	124	124	2	96	96	2	118	118	2
		DC ($n = 8$)	109	108	3	89	89	2	106	106	2
	cruise 80kt	DO ($n = 8$)	126	126	2	96	96	1	121	120	2
		DC ($n = 8$)	110	110	3	90	90	1	107	107	2
	cruise 90kt	DO ($n = 8$)	128	128	2	96	96	1	122	123	2
		DC ($n = 8$)	111	110	3	92	91	1	108	107	2
	cruise 100kt	DO ($n = 8$)	129	129	2	97	97	1	123	124	2
		DC ($n = 8$)	112	111	3	93	93	2	109	108	2
	cruise 110kt	DO ($n = 8$)	130	130	1	99	99	1	124	124	1
		DC ($n = 8$)	112	111	3	95	95	2	110	109	2
	Landing	DO ($n = 6$)	122	122	4	98	98	1	117	117	3
		DC ($n = 5$)	110	109	3	91	91	1	107	107	2

For the rotary-wings, flying at 100 and 110kt for the AS350 B2 and 140 kt for the AW119 MkII have the highest mean L_{eq} and L_{Ceq} , specially for the AS30 B2 with the left rear door open. The mean L_{eq} at 110kt with DO in the AS350 B2 is 7 dBA higher and the L_{Ceq} is up to 5 dBC than the AW119 MkII at 140kt but the AS350 B2 has lower L_{Aeq} .

For fixed-wings, both Cessna models, even with different engines, have similar interior unweighted, A-weighted and C-weighted global equivalent SPLs in all flight conditions. The C210N, C206H and EMB-820C have similar SPL during the take-off and higher SPL levels in cruise conditions. However, the BE-55 presented the lower mean L_{Aeq} during the cruise but the higher mean L_{Aeq} during the take-off.

3.4 A-weighted equivalent SPLs and 1/3-octave spectra for hearing loss risk assessment under cruise flight conditions

As in aeromedical flights using fixed-wings aircraft 70% of the total flight time is in cruise flight, and taking into account the statistical data presented in Table 5 and 6 that indicate that A-weighted SPLs in the helicopters are the highest under most typical cruise speeds (100 to 110 kt for the AS350 B2, and 130 to 140 kt for the AW119 MkII), it is reasonable to analyze hearing loss risk based on data for cruise flight both for helicopters as well as fixed wing aircraft. Global A-weighted SPLs given in Tables 5, 6 and 7 are therefore completed with 1/3-octave A-weighted global equivalent SPLs L_{Aeq} in Figure 6 for rotary-wings and in Figure 7 for fixed-wings.

Table 6: Basic statistics (mean, median and standard deviation) of unweighted, A-weighted and C-weighted global equivalent SPLs measured in the AW119 MkII during different flight stages with all doors closed (DC) and both rear doors open (DO).

Aircraft	Flight Stage		L_{eq}			L_{Aeq}			L_{Ceq}		
			mean	med	SD	mean	med	SD	mean	med	SD
			[dB]			[dBA]			[dBC]		
AW119 MkII	Take-off	DO ($n = 3$)	117	115	5	98	98	0	114	112	5
		DC ($n = 3$)	116	116	0	96	96	0	112	113	1
	cruise 40kt	DO ($n = 3$)	117	116	2	96	96	0	114	113	2
		DC ($n = 3$)	118	118	0	95	95	1	113	114	1
	cruise 50kt	DO ($n = 3$)	119	119	2	97	97	1	116	115	1
		DC ($n = 3$)	114	115	2	94	94	1	111	111	1
	cruise 60kt	DO ($n = 3$)	118	116	5	96	96	1	115	113	4
		DC ($n = 3$)	113	115	3	94	94	1	110	111	2
	cruise 70kt	DO ($n = 3$)	120	117	5	98	99	1	116	114	4
		DC ($n = 3$)	114	115	3	94	94	1	110	111	2
	cruise 80kt	DO ($n = 3$)	119	118	3	99	100	1	116	116	3
		DC ($n = 3$)	114	116	3	95	96	1	111	112	2
	cruise 90kt	DC ($n = 3$)	115	116	3	96	96	1	111	113	2
	cruise 100kt	DC ($n = 3$)	115	115	2	97	97	1	111	112	2
	cruise 110kt	DC ($n = 3$)	116	116	1	98	99	1	112	113	1
	cruise 120kt	DC ($n = 3$)	120	120	2	99	100	1	116	116	2
	cruise 130kt	DC ($n = 3$)	121	122	2	100	101	2	117	118	2
	Landing	DO ($n = 3$)	123	124	3	102	103	3	119	120	2
		DC ($n = 2$)	116	116	1	100	100	1	115	115	1



Table 7: Basic statistics (mean, median and standard deviation) of unweighted, A-weighted and C-weighted global equivalent SPLs measured in the airplanes during take-off, cruise and landing.

Aircraft	Flight Stage		L_{eq}			L_{Aeq}			L_{Ceq}		
			mean	med	SD	mean	med	SD	mean	med	SD
			[dB]			[dBA]			[dBC]		
C210N	Take-off	($n = 1$)	105*	-	-	90*	-	-	103*	-	-
	Cruise 140 kt	($n = 5$)	105	106	1	91	91	1	104	106	0
	Landing	($n = 1$)	109*	-	-	87*	-	-	105*	-	-
C206H	Take-off	($n = 1$)	106*	-	-	91*	-	-	105*	-	-
	Cruise 115 kt	($n = 7$)	107	107	1	92	91	-	107	106	1
	Landing	($n = 1$)	108*	-	-	86*	-	-	104*	-	-
BE-55	Take-off	($n = 6$)	113	113	1	97	97	1	112	112	1
	Cruise 130 kt	($n = 15$)	104	104	1	89	89	1	104	104	1
	Landing	($n = 3$)	108	109	1	91	91	0	107	107	0
EMB-820C	Take-off	($n = 1$)	106*	-	-	91*	-	-	106*	-	-
	Cruise 200 kt	($n = 13$)	103	103	1	96	96	1	103	103	1
	Landing	($n = 1$)	101*	-	-	90*	-	-	99*	-	-

*For conditions with a single measurement ($n = 1$) a single value is given instead of the mean.

For helicopters only the highest cruise speeds (110 kt for the AS350 B2, and 140 kt for the AW119 MkII) will be considered with all doors closed for both the AW119 MkII and AS350 B2.² For the fixed-wing airplanes, standard cruise speed as given in Table 4 will be considered.

It is seen that 1/3-octave bands between 50 Hz and 10 kHz are the most relevant for the global L_{Aeq} for the rotary-wings models. Also, L_{Aeq} in the AW119 MkII is slightly more pronounced in the 2 kHz to 6 kHz range, if compared to the AS350 B2.

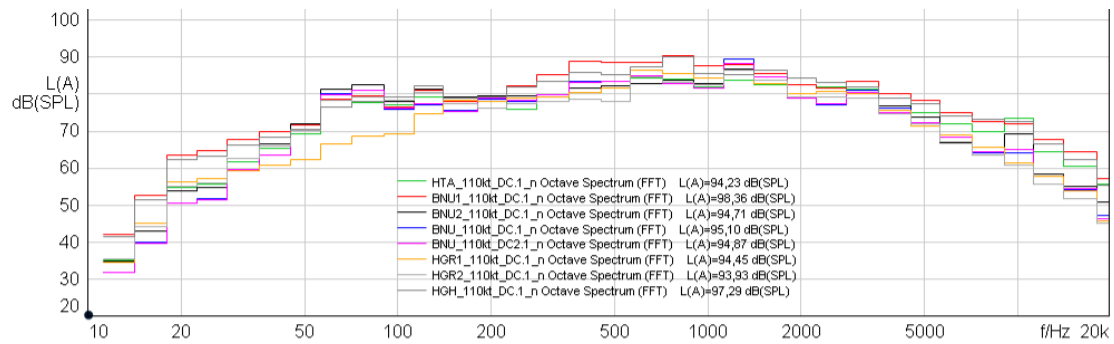
For the fixed-wings, the most relevant 1/3-octave band L_{Aeq} are found between 100 Hz and 5 kHz for all models. Mean L_{Aeq} in the C210N is 91 dBA @140kt, in the C206H 92 dBA @ 115kt, in the BE-55 89 dBA @130kt and in the EMB-820C 96 dBA @200kt.

Comparing the rotary and the fixed-wings, during cruise speed, it is found that the AS350

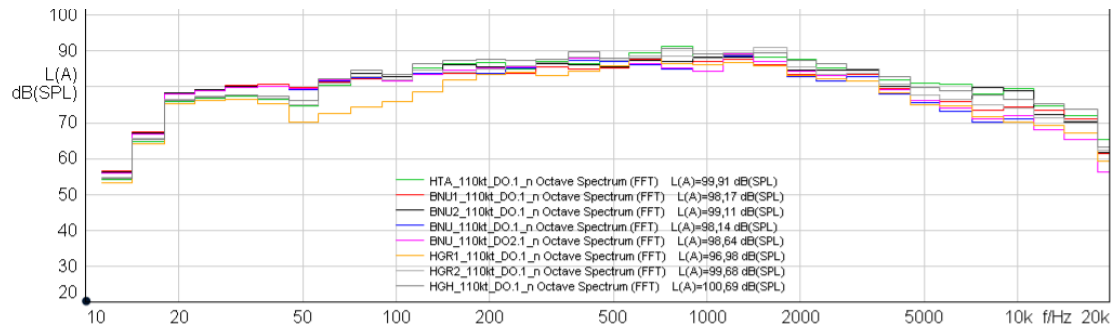
B2 when flown with closed doors and the EMB-820C have similar mean L_{Aeq} . Nevertheless, this AS350 B2 mean L_{Aeq} is up to 4 dB higher than in the C210N and the C206H and up to 6 dB higher than the mean L_{Aeq} in the BE-55. Also, the AS350 B2 has higher C-weighted global equivalent SPL comparing to the fixed-wings.

The AW119 MkII have the highest A-weighted global equivalent SPLs of all aircraft during cruise speed at 140kt with all doors closed. The mean L_{Aeq} at 140 kt is up to 10 dB higher than in the C210N and the C206H, up to 13 dB higher than in the BE-55 and up to 6 dB higher than in the EMB-820C. However, the AW119 MkII can achieve higher cruise speeds if compared to the AS350B2 and C206H and thus spends less time in this condition, reducing the total flight time and potentially reducing total noise exposure.

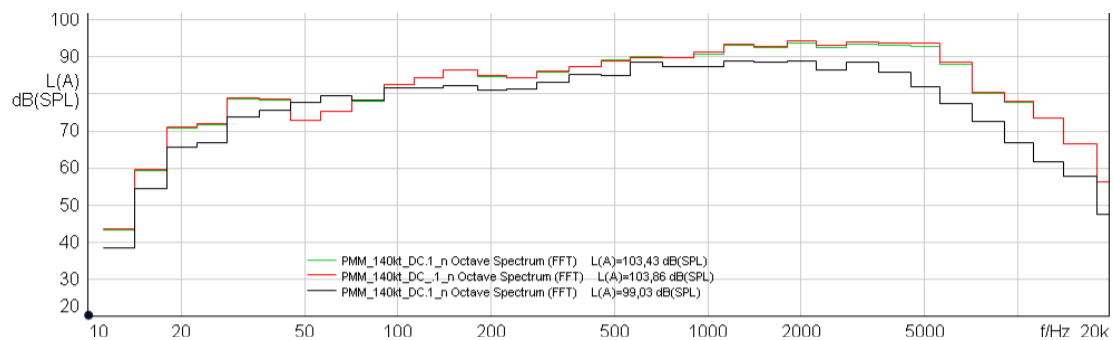
²While aeromedical transports usually occur with all doors closed even when using helicopters, in some specific situations small helicopters as the AS350 B2 might be flown with the rear doors open to accommodate the patient transversely if no aeromedical kit is installed.



(a) AS350 B2 (PR-HGR) 110kt cruise speeds DC



(b) AS350 B2 (PR-HGR) 110kt cruise speeds DO



(c) AW119 MkII (PR-PPM) 140kt cruise speeds DC

Figure 6: A-weighted 1/3-octave SPL spectrum measured in the cabins of the AS350 B2 and AW119 MkII helicopters during most usual cruise speeds. 1/3 octave-FFT analysis, FFT length 4096 samples, Hanning Window, 50 % overlap.

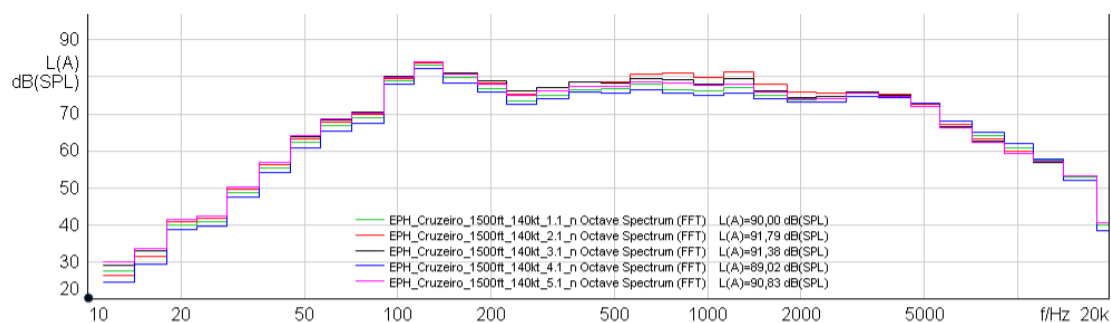
4. CONCLUSION

From calibrated noise recordings taken inside aircraft during aeromedical transports 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.

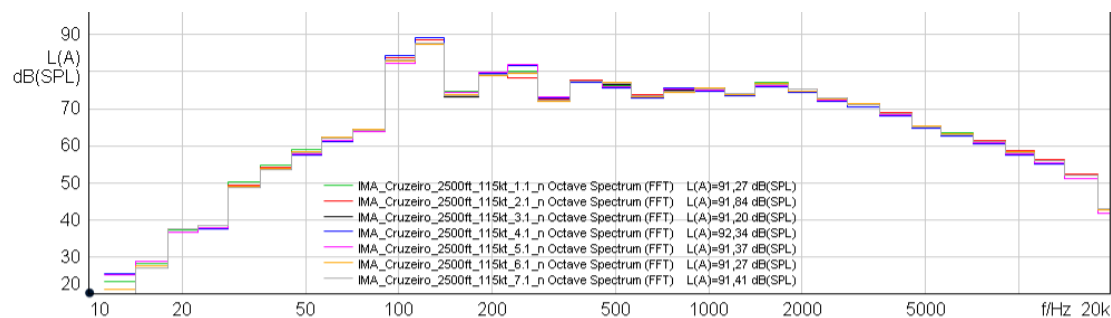
The AS350 B2 flying at 110kt with all doors closed has approximately the same mean L_{Aeq} as found in the airplanes at their respective cruise speeds. An the other hand, the AW119 MkII flying at 140kt cruise speed features highest L_{Aeq} of all aircraft during cruise speed with all doors

closed. Depending on the total duration of the flight and the percentage in cruise flight, total noise noise in the AW119 Mk II can still be lower if compared to the AS 350 B2 flying with its doors closed. When flying AS350 B2 with the left rear door open, its mean L_{Aeq} is similar to the L_{Aeq} in the AW119 MkII. This shows the importance of installing the aeromedical kit on the AS350 B2, because with the kit installed, the L_{Aeq} inside the AS350 B2 can be reduced by up to 8 dB closing the doors of the aircraft.

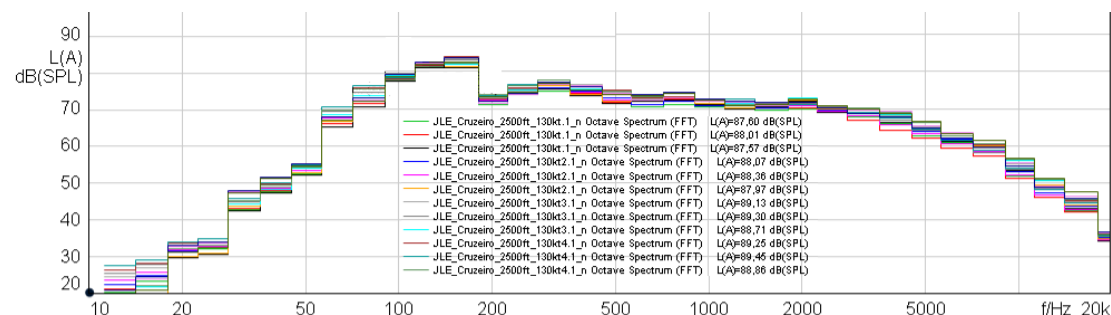
Considering the possibility of an aeromedical transport involving all airplanes, it can be said that these aircraft models have L_{Aeq} similar to



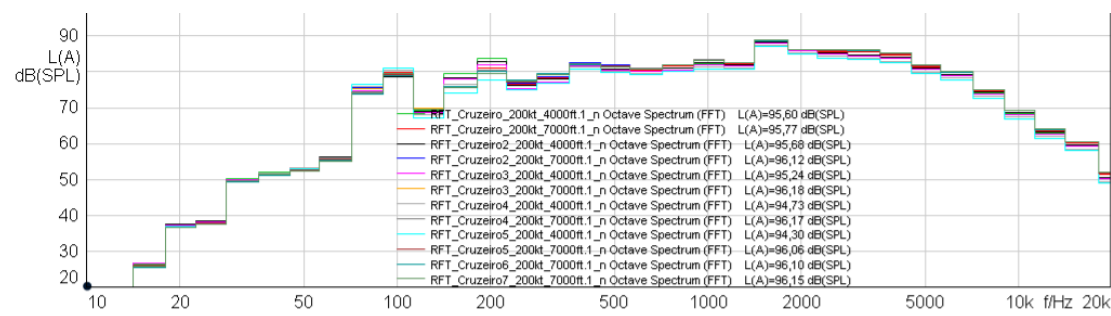
(a) C210N (PR-EPH) 140kt cruise speed



(b) C206H (PP-IMA) 115kt cruise speed



(c) BE-55 (PT-JLE) 130kt cruise speed



(d) EMB-820C (PT-RFT) 200kt cruise speed

Figure 7: A-weighted 1/3-octave SPL spectrum measured in the cabin of different fixed-wing aircraft at the aircraft's typical cruise speed. 1/3 octave-FFT analysis, FFT length 4096 samples, Hanning Window, 50% overlap.

the AS350 B2 with the doors closed. That is, there is no important difference in the sound pressure levels inside the cabins for these aircraft, so, acoustically speaking, if it is possible to carry out transports involving any kind of patients on the airplanes, it is also possible to carry

out these transports on the AS350 B2 as well. However, comparing airplanes and the AW119 MkII helicopter, the latter one would need to fly at lower speeds, e.g. 110 kt, to develop lower internal sound pressure levels comparable to the remaining aircraft.

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