

Aeroacoustic Analysis of a Generic Jet-Fighter Weapons Bay at Transonic Mach number

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Aero-acoustic analysis was conducted on the weapon bay of a generic aircraft model using frequency-based standard and high-order spectral approaches. The bay model was installed on a representative combat aircraft, incorporating doors and a store. The effect of angle of attack and store position on the aero-acoustic response within the weapon bay was analysed at a transonic Mach number of 0.90. It was found that store position and angle of attack not only influenced the appearance of the resonant mode but also the non-linear interaction, hindering in some cases the formation of harmonics and sub-harmonics of the dominant tone.

I. Nomenclature

C_P	=	pressure coefficient
D	=	store's maximum diameter (reference length), [m]
H	=	weapon bay depth, [m]
f	=	frequency, [Hz]
L	=	weapon bay length, [m]
M_∞	=	freestream Mach number
p	=	pressure, [Pa]
p_∞	=	freestream static pressure, [Pa]
q_∞	=	freestream dynamic pressure ($= \frac{1}{2} \gamma P_\infty M_\infty^2$), [Pa]
RH_n	=	n_{th} Rossiter-Heller mode
S_{ref}	=	store's reference area, [m ²]
t	=	time, [s]
T_∞	=	freestream static temperature, [K]
U_∞	=	freestream velocity, [m/s]
W	=	weapon bay width, [m]
(X, Y, Z)	=	weapon bay's Cartesian coordinate system (longitudinal, transverse, vertical), [m]
(X_s, Y_s, Z_s)	=	position of the store's leading-edge in the weapon bay coordinate system, [m]
(x, y, z)	=	store's coordinate system (longitudinal, transverse, vertical), originated at its leading-edge, [m]
α	=	angle of attack of the aircraft model, [deg]
β	=	sideslip angle of the aircraft model, [deg]
γ	=	ratio of specific heats for air
ρ	=	air density, [kg/m ³]

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II. Introduction

THE design of modern combat aircraft is strongly influenced by the requirement that weapon systems must be carried inside the airframe (internally) instead of being suspended externally on the wings and fuselage. Whilst this solution offers advantages in terms of aerodynamic drag and radar cross-section reduction, other issues arise because the intrinsic instability of the local flow, when the bay's doors are opened, poses a hazard for the weapon's safe release. Additionally, an acoustic field can develop and damage the airframe and the payload electronics. Therefore, it is essential to understand the flow phenomena within internal weapons bays and the interaction of internal stores with the bay flow field.

The literature reports numerous experimental data on the flow field within cavities, with NASA making one of the first pioneering contributions with wind tunnel data on the internal flow characteristics, acoustical spectrum, and loads exerted on a slender store model placed within the cavity for a range of flow conditions [1–4]. However, while studying a generic cavity flow can provide valuable insights, it is still a simplification of the more complex flow field generated within aircraft weapon bay configurations. One of the main differences between a generic cavity and a weapons bay configuration is the presence of the bay door, which can significantly alter the flow field within the bay, resulting in higher acoustic tones [5–10]. In addition, different flight conditions of the aircraft, such as angle of attack or sideslip angle, can significantly modify the flow field into the weapon bay [5, 9, 11]. Furthermore, stores placed within the cavity are typically non-generic [12–14], featuring complex geometries with multiple fins that can fill much of the volume (particularly air-to-ground stores). Therefore, further research is required to investigate these factors in depth.

The scope of this study was to gain further insight into the aero-acoustic response of this weapon-bay configuration and to determine how angle of attack variations and store position influenced the formation/appearance of the resonant tones. To analyse in detail all these aspects, the standard spectral analysis (of pressure signals) approach was complemented by high-order spectral analysis using the Bispectral Mode Decomposition (*BMD*) developed by Schmidt [15].

The generic aircraft model was tested at a transonic Mach number of 0.9 and three different angles of attack (-6° , 2° , and 8°). Surface pressure signals were recorded in several locations inside the cavity, and time-frequency decomposition techniques were applied to discern the salient features.

III. Methodology

A. Experimental benchmark

The study was applied to a generic aircraft model (see Fig. 1), for which wind tunnel data were available [11, 16]. The airframe incorporated twin-flanked weapons bays (WB) of rectangular shape, with a length (L) of 232 mm, width (W) of 56 mm and depth (H) of 32 mm, resulting in a length-to-depth-ratio (L/H) of 7.5 and a width-to-depth ratio (W/H) of 1.75.

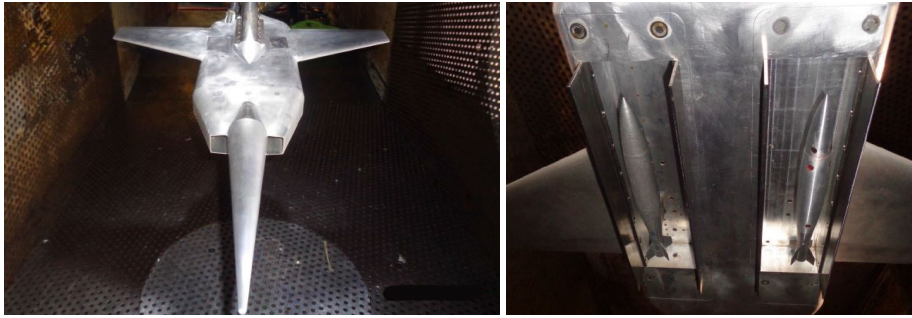


Fig. 1 Generic aircraft model. The aircraft model tested in the wind tunnel [16]

Each WB was characterised with a right-handed Cartesian coordinate system (X, Y, Z), as depicted in Fig. 2. The origin was set to mid-width at the upstream edge of the bay. The positive X -axis was in the streamwise direction, the positive Z -axis was normal to the bay ceiling and outward from it, and the Y -axis was in the cavity lateral direction, positive outboard. Several low-frequency (static) and high-frequency (dynamic) pressure transducers were installed on the surface of the right-side WB (PXXX and PDXX, as shown in Fig. 2). In the experiments, the static and dynamic pressure data were sampled simultaneously at 220 Hz and 21 kHz, respectively. For the aero-acoustic analysis in this study, only the dynamic pressure recordings of PD02 and PD17 were used; where PD02 was placed at $(X, Y, Z) = (0, 0, -0.5D)$, and PD17 was placed at $(X, Y, Z) = (0.905L, 0, -D)$.

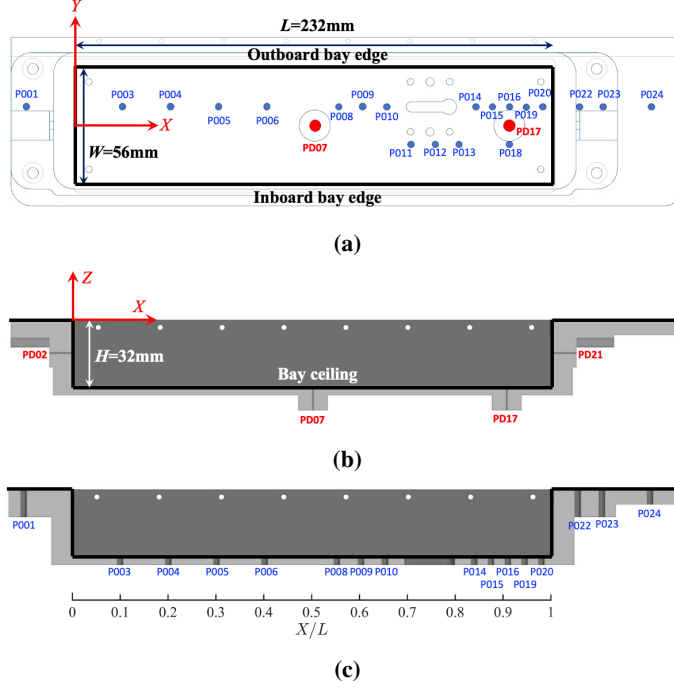


Fig. 2 Pressure transducer layout within the right-side weapons bay [16]. The static and dynamic pressure transducers are marked in blue and red, respectively. (a) Top view; (b) Side view at $Y/W = 0$; (c) Side view at $Y/W = 0.16$.

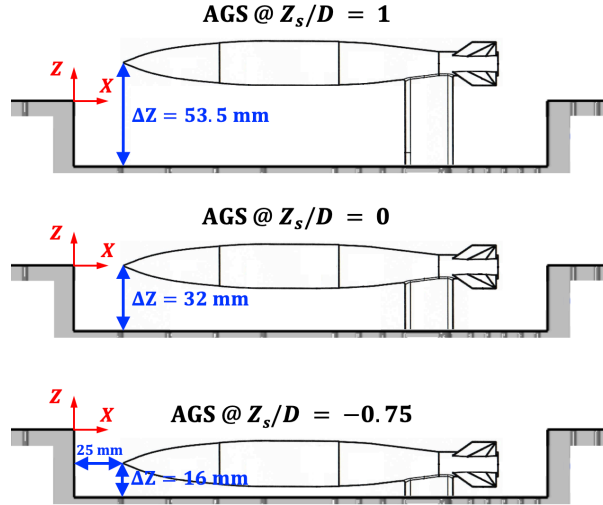


Fig. 3 Vertical locations of the store with respect to the weapon bay [16]: $Z_s/D = 1$ (top), 0 (mid), and -0.75 (bottom).

A generic air-to-ground store model (based on a modified Mk84 JDAM geometry) and two side doors were installed in each WB. The store had a length of 182 mm, a maximum diameter of $D = 21.5\text{ mm}$, and a corresponding maximum cross-section area of $S_{\text{ref}} = 362.7\text{ mm}^2$. The location of the store within the WB was evaluated by the position of its pointed leading edge, denoted by (X_s, Y_s, Z_s) , in the right-handed Cartesian coordinate system of the WB (see Fig. 3). For all configurations investigated herein, the streamwise and lateral positions of the store's leading edge were fixed at an X_s of 25 mm and Y_s of 9 mm (outwards from the plane's centreline), respectively. The store was positioned along the Z_s axis at three different stations, st1 ($Z_s/D = -0.75$), st2 ($Z_s/D = 0.00$), and st3 ($Z_s/D = 1.00$).

B. Data analysis

The non-stationary flow analysis was based on a study of the sound pressure level (SPL) of the fluctuating part of the pressure signals, defined as:

$$\text{SPL}(f) = 10 \log_{10} \left(\frac{\text{PSD}(f) \Delta f}{p_{\text{ref}}^2} \right) [\text{dB}] \quad (1)$$

where p_{ref} is the minimum audible pressure, equal to $20 \mu\text{Pa}$, which is defined as the threshold of human hearing. The PSD (power spectral density) was obtained using Welch's method [17], with the division of the original signal into segments of 2^{13} samples with a 50% overlap. On the other hand, the Overall Sound Pressure Level (OASPL) was defined as:

$$\text{OASPL} = 20 \log_{10} \left(\frac{p_{\text{rms}}}{p_{\text{ref}}} \right) [\text{dB}] \quad (2)$$

Here, p_{rms} is the root-mean-square value of the fluctuating pressure signal.

In previous studies, it was found that the underlying nature beneath the Rossiter-Heller tones is more complex than a simple resonating mechanism. Several authors [18–21] demonstrated that cavity flow is subject to non-statistically-stationary behaviour, in particular to what is called ‘mode switching’, i.e. a process whereby the dominant energy shifts from one resonant tone to another as the signal evolves in time. Additionally, it was discovered that the flow is also affected by non-linearities, such as quadratic frequency and phase coupling. These features appear in the frequency spectrum as additional peaks, accompanying the main Rossier–Heller tones. To discriminate between nonlinearly coupled waves and the spontaneously excited independent waves in a time series, it is necessary to adopt high-order (or non-linear) spectral analysis. Quadratic non-linearity implies that for a triad of frequencies f_1, f_2, f_3 the following equation is satisfied in the Fourier space:

$$f_1 \pm f_2 \pm f_3 = 0 \quad (3)$$

The zero-sum condition implies that triads form triangles in wavenumber and/or frequency spaces as shown in Fig. 4:

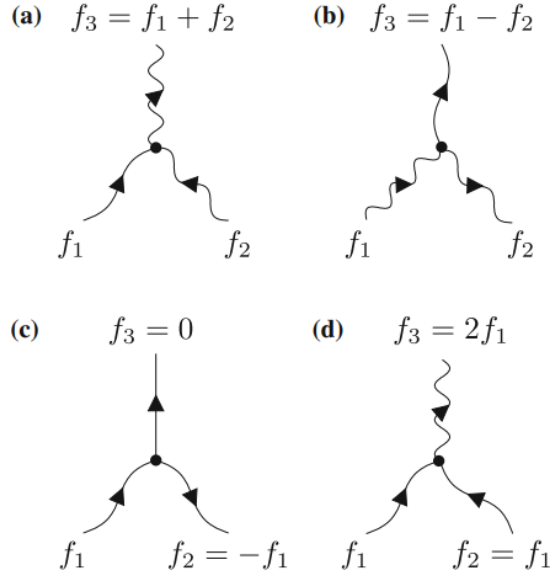


Fig. 4 Typical frequency triads: a) generic sum interaction; b) generic difference interaction; c) mean-flow deformation generated by difference-self-interaction; d) harmonic generated by sum-self-interaction (picture from [15])

The turbulent cascade, which describes the transfer of energy from large to small scales of motion, is probably the most prominent consequence of triadic interactions, although it is now well-accepted that this phenomenon governs transonic cavities' oscillatory behaviour too.

It is then necessary to develop a procedure that reveals the presence of triadic non-linear interactions. In this study, the approach of Bispectral Model Decomposition (*BMD*), developed by Schmidt, was used [15]. This procedure (not reported here for the sake of brevity) analyses a multidimensional dataset to compute the mode bispectrum modulus:

$$\Gamma = 10 \log_{10} |\lambda_1(f_k, f_l)| \quad (4)$$

In Eq.4, $\lambda_1(f_k, f_l)$ is the complex mode bispectrum (resulting from the interaction of f_k and f_l) computed according to the procedure developed by Schmidt [15]. Data can then be presented in interaction maps that quantify the average local bicorrelation between three frequency components f_k , f_l , and $f_k + f_l$ involved in a triad. The interaction map augments the bispectral modes in that it indicates regions of activity of triadic interaction.

Finally, the empirical derivation of the Rossiter-Heller modes used the standard formulation; indicating with RH_n the Rossiter-Heller frequency of the n^{th} mode, we can write:

$$RH_n = \frac{U_\infty}{L} \cdot \frac{n - 0.062(L/H)}{M_\infty \left[1 + \frac{\gamma-1}{2} M_\infty^2 \right]^{-1/2} + \frac{1}{0.57}}, \quad (5)$$

This expression, following Delprat's decomposition [10, 22], can be decomposed as:

$$f_a = \frac{U_\infty}{L} \cdot \frac{1}{M_\infty \left[1 + \frac{\gamma-1}{2} M_\infty^2 \right]^{-1/2} + \frac{1}{0.57}} \quad (6)$$

$$f_b = \frac{U_\infty}{H} \cdot \frac{0.062}{M_\infty \left[1 + \frac{\gamma-1}{2} M_\infty^2 \right]^{-1/2} + \frac{1}{0.57}} \quad (7)$$

Here, f_a is the fundamental acoustic-loop frequency, whilst f_b is the modulating frequency.

C. Wind Tunnel matrix

The geometry was tested at a Mach number of 0.9, varying angle of attack (3 cases) and store position (3 cases). This resulted in 9 cases in totals. It must be specified that during all the tests, only the position of the store in the left weapon bay was changed, whilst the store in the right WB was kept fixed at $Z_s/D = 0$.

Table 2 Test conditions for the simulated runs (from experiments [16]).

M_∞	st	Z_s/D	α [deg]	β [deg]	p_∞ [Pa]	T_∞ [K]	U_∞ [m/s]	q_∞ [Pa]
0.9	1	-0.75	-6	0	97,369	266	294	55,208
			+2		99,159	267	295	56,223
			+8		99,434	268	295	56,379
	2	0	-6		99,422	266	294	56,372
			+2		99,043	269	296	56,157
			+8		99,974	268	295	56,685
	3	1.00	-6		96,733	261	292	54,848
			+2		98,319	265	294	55,747
			+8		97,767	265	294	55,434

IV. Results

A. General aero-acoustic analysis

The initial analysis of the WT dataset focused on exploring the angle of attack and store position effects on the weapons bay acoustic excitation (OASPL) and spectra (SPL). Table 3 summarises the OASPL values calculated for all probes in all tests. According to the case analysed, OASPL varied between 158 dB and 177 dB. The major outcome was that, independently of the probe taken into consideration and the store position, the highest values were observed for

$\alpha = 2^\circ$. Similarly, the highest OASPL was observed at the rear wall (PD21) whilst the lowest was at the front wall (PD02). The effects of store position were such that the configurations with the store placed inside the cavity (st1, st2) experienced higher acoustic excitation than the configuration with the store having cleared the shear layer (st3). On the other hand, the effect of angle of attack was such that decreasing or increasing incidence from $\alpha = 2^\circ$ resulted in a reduction of the OASPL. The worst-case scenario (i.e. the condition for which the probes reported the highest OASPL) was observed for st2 at $\alpha = 2^\circ$. On the other hand, the case where OASPL was at a minimum was observed for st3 at $\alpha = -6^\circ$.

Table 3 OASPL values for all the runs/probes

st	Z_s/D	α [deg]	OASPL[dB]			
			PD02	PD07	PD17	PD21
1	-0.75	-6	160.65	163.67	160.37	170.57
		+2	164.38	169.69	165.26	175.68
		+8	158.70	164.00	161.11	170.72
2	0.00	-6	161.28	167.48	163.20	172.96
		+2	165.21	172.49	166.50	176.56
		+8	160.44	168.13	162.53	172.68
3	1.00	-6	158.46	165.97	159.19	169.11
		+2	163.58	169.85	165.11	176.32
		+8	162.03	168.64	162.46	173.12

OASPL and SPL varied with angle of attack and store position. At $\alpha = -6^\circ$ (see Fig.5), the spectrum was dominated by the second Rossiter-Heller tone, although major influences were observed according to store position. When the store was placed inside and outside the cavity (st1 and st3), RH_2 prominence above background noise was within 10 dB, with SPL values ranging from 145 dB for PD02 to 155 dB for PD21. For the case where the store was inside the cavity (st1), RH_1 was also present, although the peak was not in accordance with the empirical predictions (318 Hz in the experimental data compared to 259 Hz of Eq.5). In terms of acoustic power, RH_1 was stronger than RH_2 by 2 dB except for PD07, where the two modes were similar. If the store was placed in the shear layer (st2), all tones vanished except for RH_2 , which increased its power and prominence, achieving SPL values above 160 dB. In this configuration, RH_3 was present too, although its power was considerably inferior and barely above the background noise. A similar spectrum (with both RH_2 and RH_3) was observed for the configuration with the store outside the cavity (st3). Nevertheless, in this case, RH_2 prominence above background noise was considerably inferior and comparable with RH_3 . The findings indicated that the spectrum changed qualitatively when the store was outside the cavity volume (st2 and st3), suggesting alterations of the resonance mechanism.

At $\alpha = 2^\circ$ (see Fig.6), the spectrum structure changed, and, in accordance with OASPL results, the level of excitation increased. The SPL, at all store stations, was characterised by four tones, of which RH_2 was the strongest, achieving more than 160 dB, with the highest value observed at PD21 (for St2), with 172 dB. RH_3 was well defined at PD02, PD17, and PD21, and, in all configurations, was the second most intense tone, with SPL values ranging from 150 dB to 160 dB. RH_1 could be observed at all probes, although it achieved the highest prominence when the store was placed inside the cavity (st1). Finally, when the store was placed in the shear layer and outside the cavity (st2 and st3), RH_4 also appeared in the spectrum, although its central frequency was considerably different from the theory-predicted value.

At $\alpha = 8^\circ$ (see Fig.7), the spectrum was still dominated by RH_2 . RH_3 was present as well in all probe spectra except for PD07. Likewise RH_2 , achieved higher SPL values when the store cleared the cavity with respect to the case where the store was still in the bay. On the other hand, RH_1 failed to manifest, and at the associated frequency band, only noise was present. Table 4 and 5 summarise the resonant modes observed at PD02 and PD21, respectively.

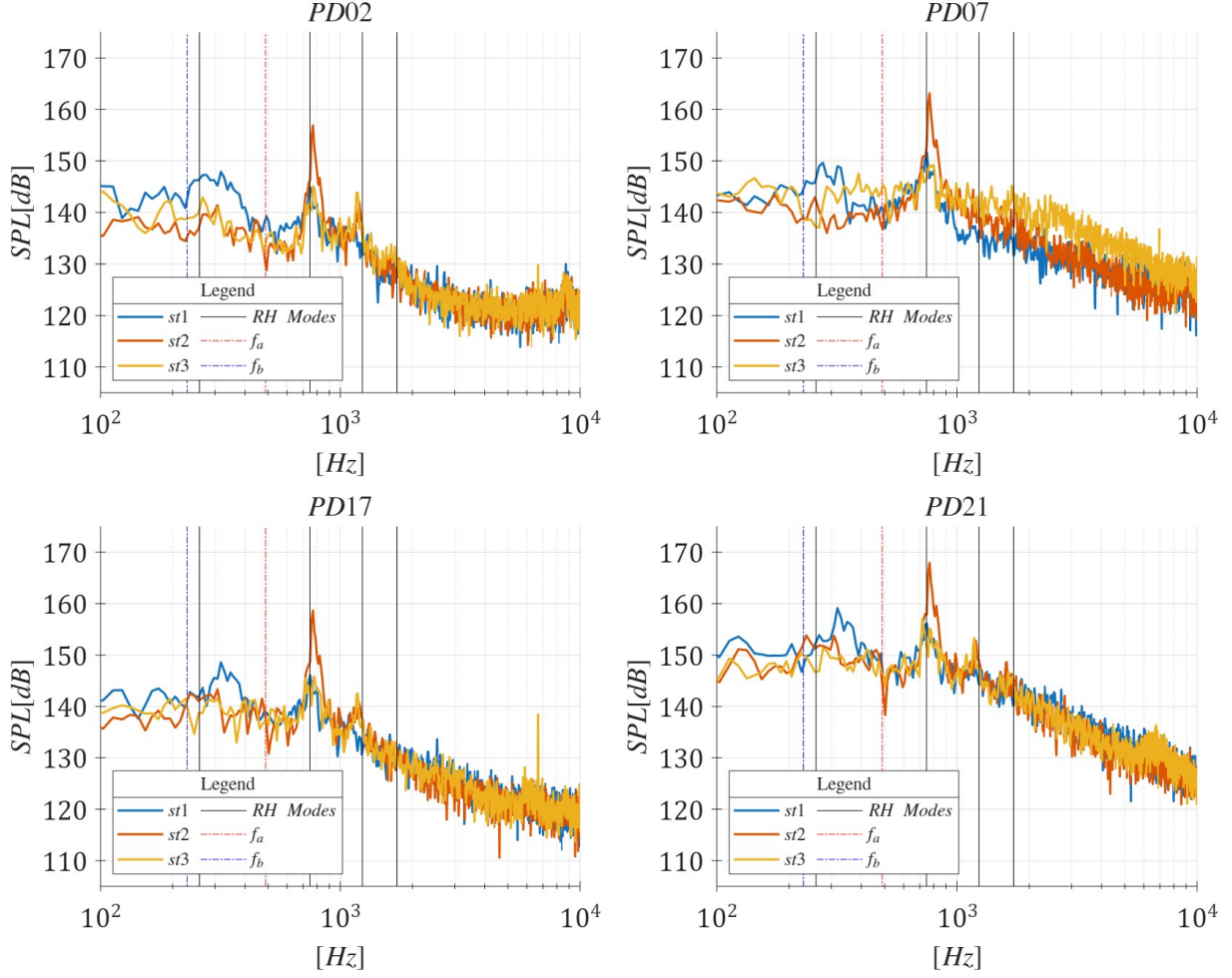


Fig. 5 Acoustic pressure spectra for the dynamics probes at 3 store's positions, $\alpha = -6^\circ$. Markers indicate major Rossiter-Heller tones (black) and Delprat's modes (red/blue).

Table 4 Summary of SPL data for PD02

st	Z_s/D	α [deg]	RH ₁		RH ₂		RH ₃		RH ₄	
			[Hz]	[dB]	[Hz]	[dB]	[Hz]	[dB]	[Hz]	[dB]
1	-0.75	-6	318	159.1	749	156.9	-	-	-	-
		+2	-	-	800	170.7	1282	152.0	-	-
		+8	-	-	728	155.9	1087	151.7	-	-
2	0.00	-6	-	-	769	168.0	1200	152.7	-	-
		+2	-	-	800	171.9	1251	159.5	1610	152.8
		+8	-	-	759	162.9	1159	154.1	-	-
3	1.00	-6	-	-	718	157.0	1179	153.3	-	-
		+2	-	-	779	165.3	1210	159.9	1651	150.5
		+8	-	-	728	161.5	1148	155.4	1610	154.1
		Theory	259	-	747	-	1235	-	1728	-

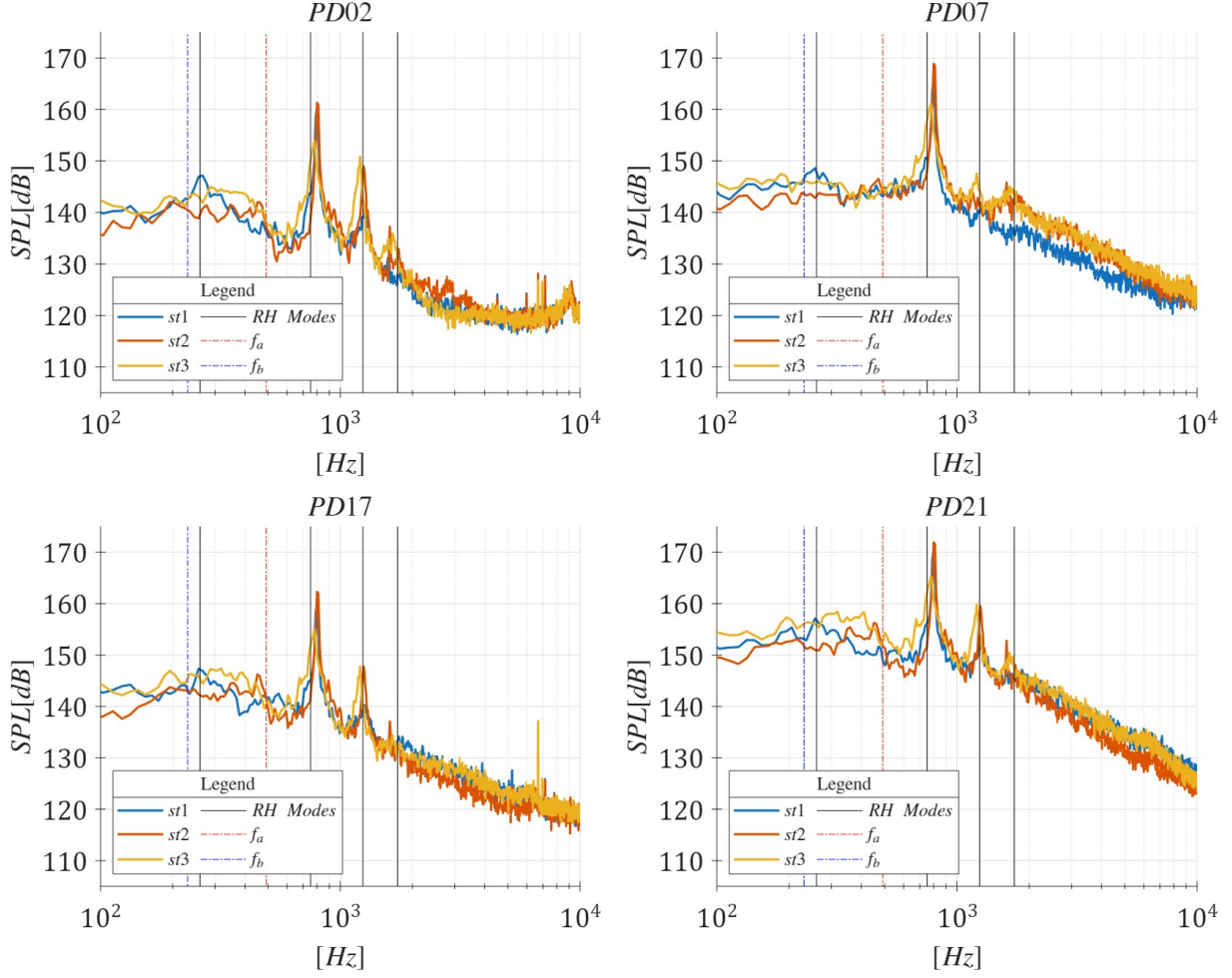


Fig. 6 Acoustic pressure spectra for the dynamics probes at 3 store's positions, $\alpha = +2^\circ$. Markers indicate major Rossiter-Heller tones (black) and Delprat's modes (red/blue).

Table 5 Summary of *SPL* data for *PD21*

st	Z_s/D	α [deg]	RH ₁		RH ₂		RH ₃		RH ₄	
			[Hz]	[dB]	[Hz]	[dB]	[Hz]	[dB]	[Hz]	[dB]
1	-0.75	-6	318	147.9	749	144.9	-	-	-	-
		+2	267	147.2	800	160.6	1261	141.3	-	-
		+8	-	-	769	142.0	1087	138.2	-	-
2	0.00	-6	-	-	769	156.9	1200	142.0	-	-
		+2	-	-	810	161.0	1261	148.2	1610	137.3
		+8	-	-	769	151.0	1169	143.3	-	-
3	1.00	-6	-	-	769	145.1	1179	143.9	-	-
		+2	-	-	779	153.9	1210	150.8	1661	135.8
		+8	-	-	728	149.0	1138	147.1	-	-
		Theory	259	-	747	-	1235	-	1728	-

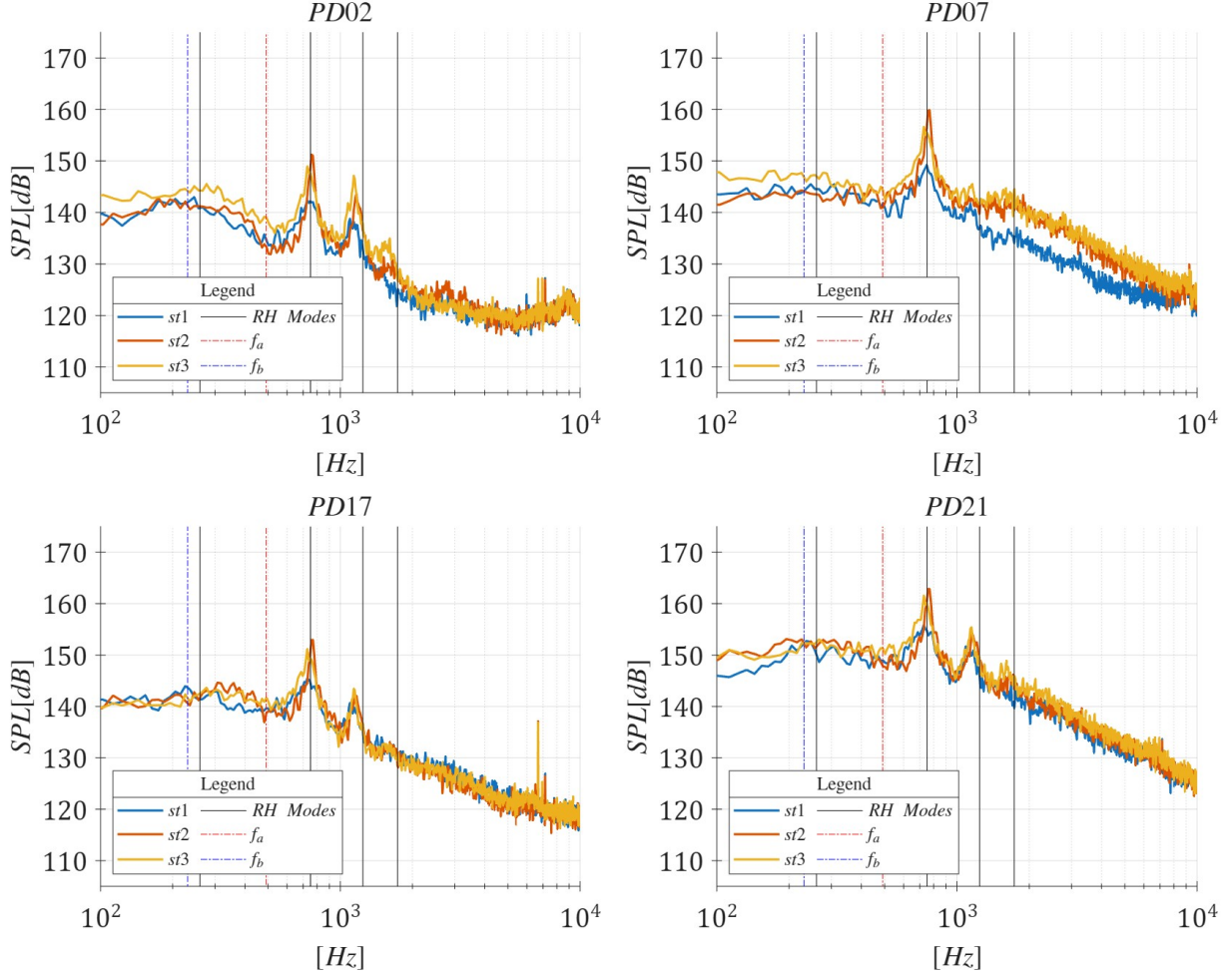


Fig. 7 Acoustic pressure spectra for the dynamics probes at 3 store's positions, $\alpha = +8^\circ$. Markers indicate major Rossiter-Heller tones (black) and Delprat's modes (red/blue).

B. Non-Linear Interactions Analysis

An optimal dataset to be processed with BMD would typically require high values of sampling not just in the time domain, but also in the spatial domain. Whilst the former is not a problem in experimental facilities, the latter has limitations. Nevertheless, given the standing nature of the resonant mechanism of cavity flow, a few probes sparse in the physical domain would still be capable of capturing the dominant non-linear features governing the bay fluid dynamics. Hence, for the aim of this study, it was considered sufficient to generate the mode bispectral maps using the combination of the readings from PD02 and PD07.

Figure 8 reports BMD maps for all the cases, with rows representing variation in store position, and columns representing variation in the angle of attack. These maps clearly showed that a common feature always appeared in the bispectral maps represented by the interactions of the 2nd Rossiter-Heller mode (which spectral analysis confirmed to be the dominant mode).

All maps presented dominant peaks at the (f_1, f_2) frequency couples of $(RH_2, -RH_2)$, $(RH_2, 0)$, (RH_2, RH_2) , $(2RH_2, -RH_2)$:

- The triads $(RH_2, -RH_2)$ and $(RH_2, 0)$ represented the interaction of RH_2 with the mean flow and the relative energy transfers, that is, from RH_2 to the mean flow, the former, and vice versa, the latter.

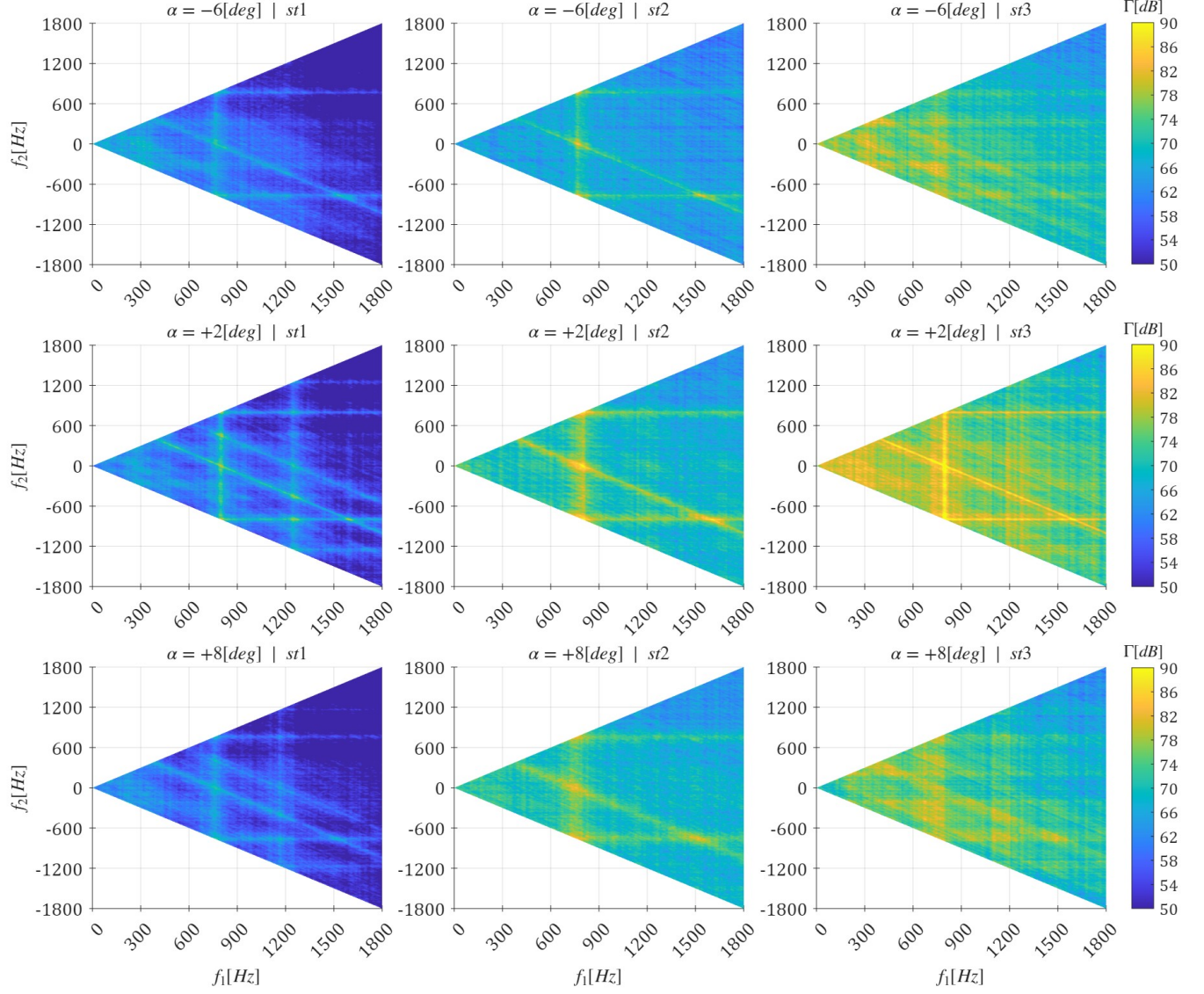


Fig. 8 Bispectral Mode Decomposition maps.

- The triads (RH_2 , RH_2) and ($2RH_2$, $-RH_2$) evidenced the first harmonic of RH_2 , with the former indicating the passage of energy towards the harmonic, and the latter the decomposition of the harmonic back to the original frequency.

Although the intensity and the sharpness of these two triads varied from configuration to configuration, it was always possible to evidence them in the maps, and hence they represented a dominant feature of the cavity. The different positions of the store had the effect of increasing the values of Γ , although the nature of the maps did not change qualitatively. The maximum (for constant values of the angle of attack) was observed at st3, whilst the minimum was at st1. Such a finding indicated a strong tendency by the bare cavity to generate frequency triads (as shown in previous similar studies on cavity flows), with the store acting like a disturbance, in the sense of a weakener of the non-linear energy transfer between resonating modes. On the other hand, the angle of attack influenced the sharpness of the peaks. The configuration, at $\alpha = 2^\circ$, was the one where Γ peaks were more distinct. By increasing or decreasing the angle of attack, although the peaks persisted, they became more diffuse and tended to be spread over bigger frequency bandwidths.

This phenomenon could be traced back towards the influence of incidence on the cavity flow. Values of angle of attack different from zero, apart from generating secondary flows impacting the cavity, also introduced a mean-flow velocity component towards/away from the weapons bay. This influenced the resonance mechanism, reducing the cohesion of the resonant modes, and in a cascade mechanism of the non-linear interactions. Secondly, the upstream boundary layer status was changed as well upon changing the incidence, and for positive values of the angle of attack, the tendency was to increase its thickness, which in turn damped the resonance mechanism as shown in previous studies (see, for example [5, 10]). Hence, the net result was that, at $\alpha = 8^\circ$ and $\alpha = -6^\circ$, the maps appeared as blurred, smoothed versions of those at $\alpha = 2^\circ$.

From this analysis, it was also possible to determine that what the spectral analysis marked as RH_4 (see Table 4 and Table 5) was in reality the first harmonic of RH_2 , explaining why the observed resonant frequency differed consistently from the theoretically predicted value.

Apart from these two dominant interactions, other features could be extracted from the bispectral maps. These were observed at $\alpha = 2^\circ$ and $\alpha = 8^\circ$ for the configuration with the store inside the cavity (st1) and at all angles of attack when the store was outside the cavity (st3). These additional triads involved the generation of the first subharmonic of RH_2 (labelled $1/2RH_2$) and the appearance of RH_3 :

- The triads $(RH_2, -1/2RH_2)$ and $(1/2RH_2, 1/2RH_2)$ represented the generation and annihilation of the first subharmonic of RH_2 .
- The triads $(RH_2, 1/2RH_2)$ and $(RH_3, -1/2RH_2)$ represented the interaction of RH_2 with its first subharmonic which generated RH_3 . This energy transfer was also observed from the couple of triads represented by $(RH_2, 1/2RH_2)$ and $(RH_3, -RH_2)$.
- The triads $(RH_3, 0)$ and $(RH_3, -RH_3)$ represented the interaction of RH_2 with the mean flow.
- The triads $(1/2RH_2, 0)$ and $(1/2RH_2, -1/2RH_2)$ represented the interaction of $1/2RH_2$ with the mean flow.

Considering that none of these interactions was observed when the store was placed in the shear layer (st2), it could be concluded that such non-linear behaviour was a direct consequence of the instabilities generated inside the shear layer. The hypothesis was that, upon placing the store inside the shear layer, such non-linear energy transfer between energy modes was hindered, and only the strongest ones related to the dominant tone (RH_2) remained. The fact that these additional triads did not appear when configuration st1 was placed at $\alpha = -6^\circ$ but did appear for positive angles of attack would suggest that, whilst the store inside the cavity still interfered with harmonic and sub-harmonic generation, its effects were not so marked as when it directly influenced the shear layer oscillations. On the other hand, when the store cleared both cavity and shear layer (st3), the cavity was let free to establish its natural flow dynamics behaviour and angle of attack variations could not hinder the formation of the non-linear interactions. Notably, these mechanisms were so well established that also RH_3 and $1/2RH_2$ interacted with the mean flow.

Finally, it was shown for RH_4 , it could be assumed that what the spectral analysis marked as RH_3 (see Table 4 and Table 5) was in reality the interaction of RH_2 with its first subharmonic $1/2RH_2$.

Table 6 Summary of relevant triads observed from BMD analysis.

st	Z_s/D	α [deg]	
		-6	+2 and +8
1	-0.75	$(RH_2, -RH_2) \rightleftharpoons (RH_2, 0)$ $(RH_2, RH_2) \rightleftharpoons (2RH_2, -RH_2)$	$(RH_2, -RH_2) \rightleftharpoons (RH_2, 0)$ $(RH_2, RH_2) \rightleftharpoons (2RH_2, -RH_2)$ $(RH_2, 1/2 RH_2) \rightleftharpoons (RH_3, -1/2 RH_2)$ $(RH_2, 1/2 RH_2) \rightleftharpoons (RH_3, -RH_2)$ $(RH_2, -1/2 RH_2) \rightleftharpoons (1/2 RH_2, 1/2 RH_2)$ $(RH_3, 0) \rightleftharpoons (RH_3, -RH_3)$
2	0.00	$(RH_2, -RH_2) \rightleftharpoons (RH_2, 0)$ $(RH_2, RH_2) \rightleftharpoons (2RH_2, -RH_2)$	
3	1.00	$(RH_2, -RH_2) \rightleftharpoons (RH_2, 0)$ $(RH_2, RH_2) \rightleftharpoons (2RH_2, -RH_2)$ $(RH_2, 1/2 RH_2) \rightleftharpoons (RH_3, -1/2 RH_2)$ $(RH_2, 1/2 RH_2) \rightleftharpoons (RH_3, -RH_2)$ $(RH_2, -1/2 RH_2) \rightleftharpoons (1/2 RH_2, 1/2 RH_2)$ $(RH_3, 0) \rightleftharpoons (RH_3, -RH_3)$ $(1/2 RH_2, 0) \rightleftharpoons (1/2 RH_2, -1/2 RH_2)$	

V. Conclusions

This study analysed the aero-acoustic response of the flow around a generic aircraft with two rectangular weapons bays incorporating a generic air-to-ground store. Such generic aircraft geometry was simulated at three angles of attack and three store positions, for a total of nine different cases. Pressure recordings were analysed using the standard approach with the derivation of the OASPL values and the SPL spectra, and via higher order spectral analysis through the Bispectral Mode Decomposition approach. The spectral analysis indicated that the angle of attack effect was to reduce the severity of both the resonant tones and the overall acoustic load. The maximum, in all store configurations, occurred at $\alpha = 2^\circ$. Increasing or reducing the incidence reduced the acoustic resonance of the weapons bay. The store position did influence cavity response, too, and when the weapon was placed inside the cavity or in correspondence with the edge, on average, both SPL and OASPL achieved higher values with respect to the case when the store was outside the cavity. The BMD revealed the presence of several non-linear interactions, of which the dominant (and always present) was represented by RH_2 , its first harmonic and the mean flow. Other interactions involving the first subharmonic of RH_2 were observed as well, although these failed to materialise in some cases. In general, it was observed that the effect of store position was to change the intensity of the interactions, such as when it was placed inside, it hampered the non-linear mechanism. The strongest evidence was observed for st2, where the placing of the store inside the shear layer completely cancelled all non-linear effects apart from the ones involving the exchange of energy of RH_2 with its first harmonic and the mean flow. The variation of the angle of attack had much less pronounced effects, and moving away from $\alpha = 2^\circ$ changed the cavity's non-linear nature only when the store was inside the cavity. Finally, it was demonstrated that what the spectral analysis indicated as RH_1 , RH_3 , and RH_3 , they were, in reality, a manifestation of the non-linearity of RH_2 , with the generation of its first subharmonic, identified as the frequency of RH_1 , its first harmonic, identified as the frequency of RH_4 , and its self interaction with its first subharmonic, identified as the frequency of RH_3 .

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