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BROADBAND NOISE REDUCTION USING ACOUSTIC METAMATERIAL IN DG SET

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Abstract: The developed resonant AMM is tested on 30 KVA capacity generator assembly for air borne noise reduction in order to enhance broadband noise reduction. This study is performed to demonstrate the performance of resonant type acoustic metamaterial over conventional sound absorbing material for broadband noise reduction. It is established from the present study that the broadband noise reduction can be enhanced by the use of Polyimide foam treated with detuned Helmholtz resonators and Quarter wave tubes. Here, resonators and QW tubes helps to reduce the low and medium frequency noise and Polyimide helps to reduce high frequency noise. The AMM is so designed that the split modes developed when tuned HRs are coupled to any acoustic cavity is also addressed by introducing detuned HRs and QW Tubes tuned to these virtual split modes. Further emphasis has been made on what type of low and medium frequency modes to be selected for better noise reduction.

Numerical modeling is carried out to determine the acoustic cavity modes of the enclosure by exiting the cavity using a monopole source kept at the center. For numerical analysis Boundary element method is selected and performed using commercial software VA One. Resonators and quarter wave tubes tuning within polyamide foam and coupling to cavity is carried out in VA One software. The pressure response inside the cavity with and without resonant metamaterial based enclosure is captured at different locations inside the cavity to determine the overall sound pressure level inside the cavity. The difference between the SPLs with and without enclosure is calculated to determine the amount of noise reduced inside the cavity. The numerical data is validated using the experimental procedures on a real time 30KVA capacity generator. From the numerical and experimental procedures, it is established that 26 dB noise is reduced from the generator.

***Key Words* – Polyimide foam, Helmholtz resonator, metamaterial, broadband.**

I. INTRODUCTION

Machinery noise above 80 dBA imposes major threat to humans who are exposed to it for prolonged durations. One such kind of system is a Diesel Generator system which produces noise of the order 98 dBA. Commercially, available DG Set noise is reduced using engine exhaust silencer and metal enclosure with air vents and normal sound absorbing material. The amount of noise reduced with muffler and enclosure is limited due to inefficiency to reduce low frequency noise. In order to increase the low and medium frequency noise reduction and over all noise reduction a resonant based acoustic metamaterial is designed and developed. For this purpose, a Polyimide foam based enclosure with detuned Helmholtz resonators is selected for the development of resonant AMM.

II. OBJECTIVE:

To test the 30 KVA capacity generator assembly, for ABN reduction and provide solution by the use of Resonant Acoustic Metamaterial (AMM). Polyimide foam and detuned Helmholtz resonators are selected for the development of resonant AMM.

Specifications of Gen Set:

Power Rating	: 30 KVA
DG Size L x W x H	: 2000 X 900 X 1420 (Including Base) (mm)
Place of Test	: GVK CAMS premises

III. TEST PROCEDURE:

The test was carried out using SINUS SOUNDBOOK MK2 DAQ with SAMURAI analysis software. Four MICROTECH GEFELL GMBH ½'' random incidence microphones are used for capturing the pressure data at predefined locations around the Gen Set as shown in Figure 1. Class 1 sound level meter of make SINUS Messtechnik Gmbh is used to measure the sound pressure levels at the microphone locations. The test is carried out in four stages on all four sides and top of the Gen Set near muffler. They are as follows:

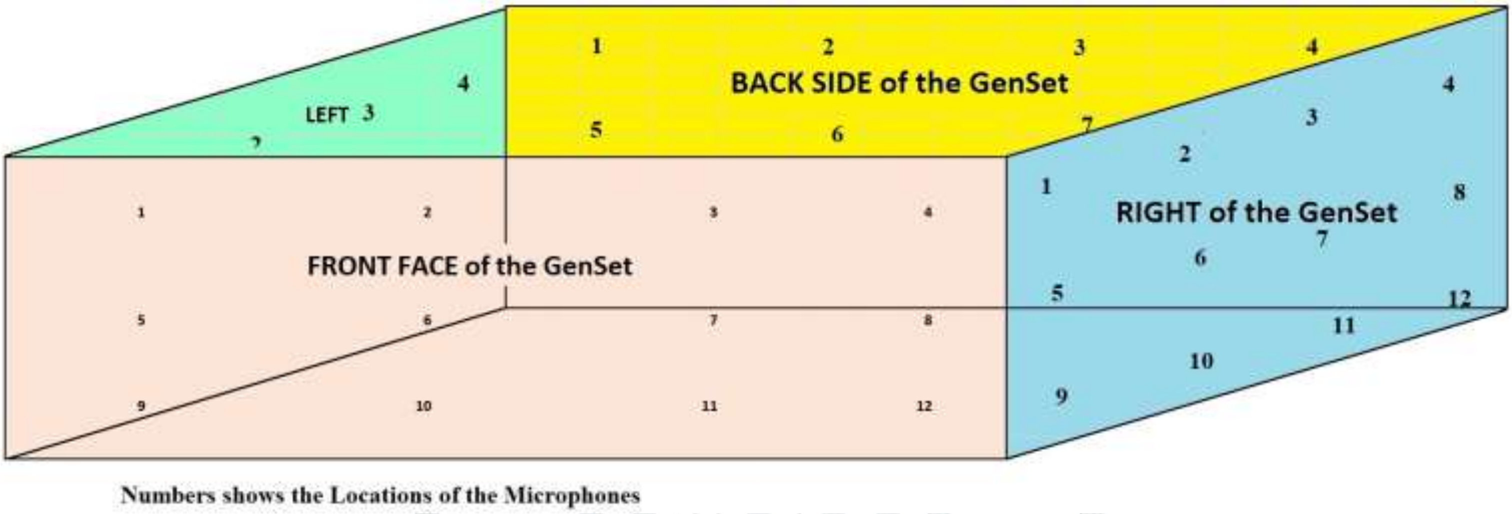

Figure 1: Locations of the microphones on the Generator Assembly

Stage 1: Sound Pressure Level measurement of the bare Gen Set
Stage 2: SPL measurement with manufacturer's metal casing with sound absorbing foam
Stage 3: SPL measurement with metal casing covered with polyimide foam
Stage 4: SPL measurement with coupled resonator polyimide foam based AMM.

Figure 2: Photograph of the 30 KVA bare Generator Assembly with casing

IV. **Results & Discussion**

Airborne Noise Analysis: The noise level is captured from 20 Hz to 20000 Hz and was plotted in 1/3rd Octave band. The microphones were kept on all the four sides and top of the Gen Set at 1m away facing perpendicular to the Gen Set. Figure 1 shows the positions of both the microphones. Figure 2 & 3 shows the test setup, bare Genset and manufacturer's metal casing.

The sound pressure level in decibels with A weighting is measured using SINUS Class 1 Sound Level Meter. The averaged sound pressure level on all the faces and at all four stages is shown in table 1. From the table it is clear that SPL decrease is enhanced by the use of resonant type acoustic metamaterial. When Stage I & Stage IV are compared it is ascertained that maximum noise reduction of 26.8 dB is achieved on front side of the resonator which is facing the cellar or operator.

The noise reduction can further be enhanced when the exhaust muffler is redesigned by incorporating acoustic metamaterial inside the muffler as it was observed from the Table 1 that there is more noise on the left and front side of the Gen Set where engine exhaust is present. It is also observed that the noise is increasing as we move from top to bottom of the measurement locations. This can be due to the influence of structure borne noise as there is no floor isolation present for the Gen Set.

Table 1: Sound Pressure levels in dBA for Generator at locations shown in Figure 1

S. No	Stages	Position	Sound Pressure Level of Microphones, dBA												
			Mic 1	Mic 2	Mic 3	Mic 4	Mic 5	Mic 6	Mic 7	Mic 8	Mic 9	Mic 10	Mic 11	Mic 12	Overall SPL
1	I Bare Gen Set	Front	98.6	95.7	95.0	93.1	98.8	95.9	95.1	93.3	99.0	96.1	95.3	93.3	96.2
2		Back	96.6	94.2	94.0	91.7	96.9	94.5	94.2	91.8	97.2	94.7	94.4	92.0	94.7
3		Left	100	98.2	97.5	96.2	100.3	98.8	98.0	97.2	101	99.7	98.8	98.2	98.9
4		Right	95.0	93.5	91.7	89.9	95.8	94.2	92.8	91.4	96.5	94.9	93.5	92.8	93.9
5		Top	99.5	98.2	97.5	96.1	NA								98.0
6	II Company Metal casing with foam	Front	87.8	87.4	85.3	84.9	88.5	88.2	85.3	84.5	89.0	88.1	85.9	84.7	86.9
7		Back	88.2	88.0	86.0	84.3	89.1	89.1	86.6	85.6	89.6	89.1	86.5	86.2	87.7
8		Left	90.1	89.2	88.8	88.1	90.3	89.5	89.1	88.3	NA				89.2
9		Right	88.2	85.6	85.6	84.8	88.4	86.7	86.1	84.7					86.5
10		Silencer	91.6	91.2	89.7	88.3	NA								90.4
11	III Metal casing with Polyimide foam alone	Front	75.7	75.3	74.7	73.5	76.7	76.4	74.9	74.3	82.3	81.8	77.3	75.5	77.5
12		Back	77.9	75.4	73.8	73.0	79.7	76.7	76.4	75.0	80.6	79.1	77.4	77.4	77.4
13		Left	79.3	79.0	78.7	78.3	80.7	80.1	79.3	78.9	NA				79.4
14		Right	76.1	75.6	75.5	74.5	77.4	76.0	75.8	75.2					75.8
15		Silencer	79.5	78.7	77.9	77.3	NA								78.4
16	IV Resonant type Acoustic Metamaterial (AMM)	Front	69.8	68.0	67.5	66.7	70.5	69.7	68.6	67.2	72.0	70.5	70.1	69.0	69.4
17		Back	71.8	70.3	68.1	66.3	73.2	71.2	69.8	68.7	74.5	73.2	70.9	69.7	71.2
18		Left	73.7	72.9	71.2	71.0	74.8	73.4	72.5	71.8	NA				72.8
19		Right	72.4	71.5	70.2	69.7	73.5	72.7	71.9	70.5	NA				71.7
20		Silencer	73.5	72.5	71.8	70.5	NA								72.2

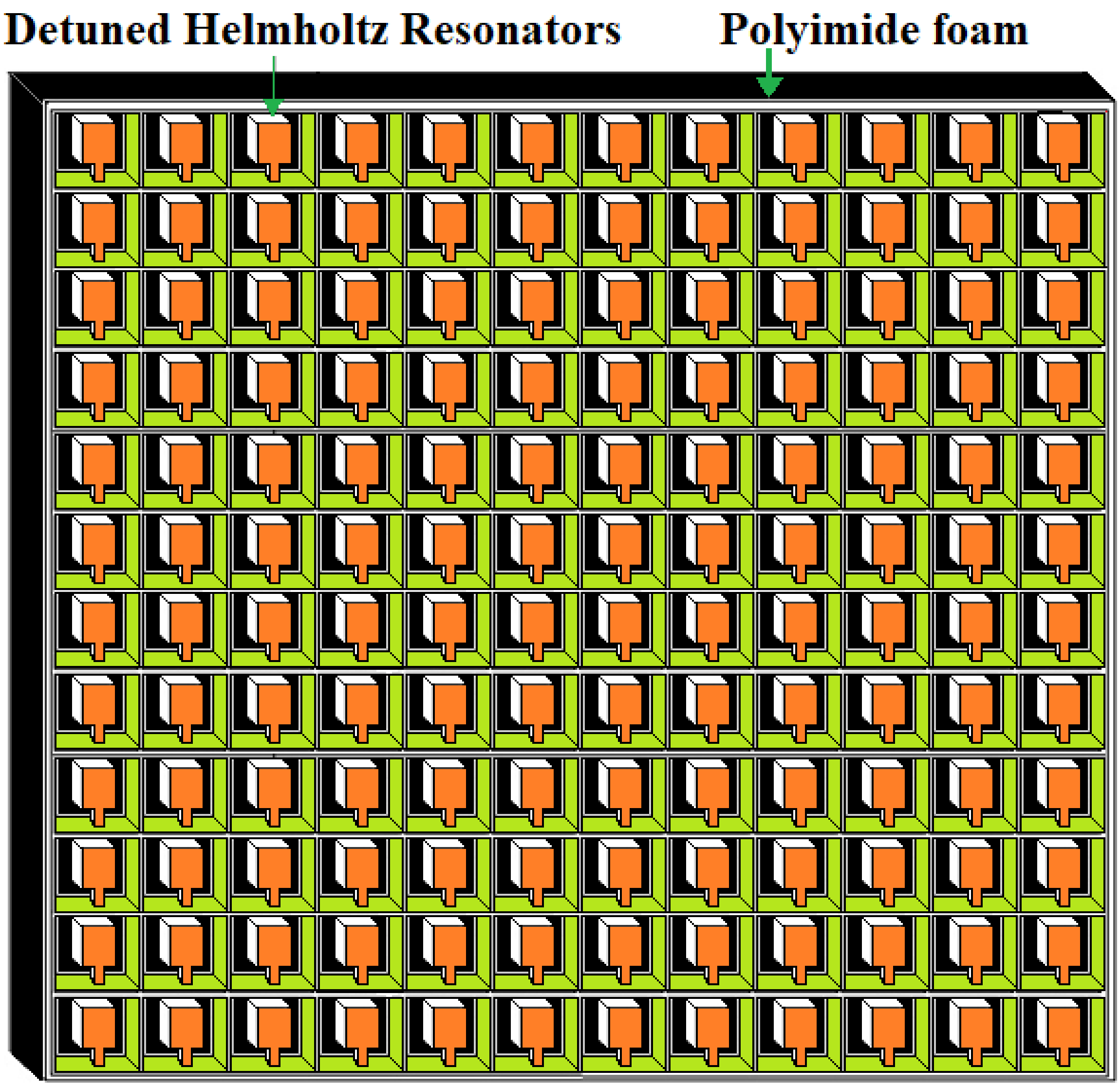

Figure 0: Schematic diagram of the Resonant Acoustic Metamaterial

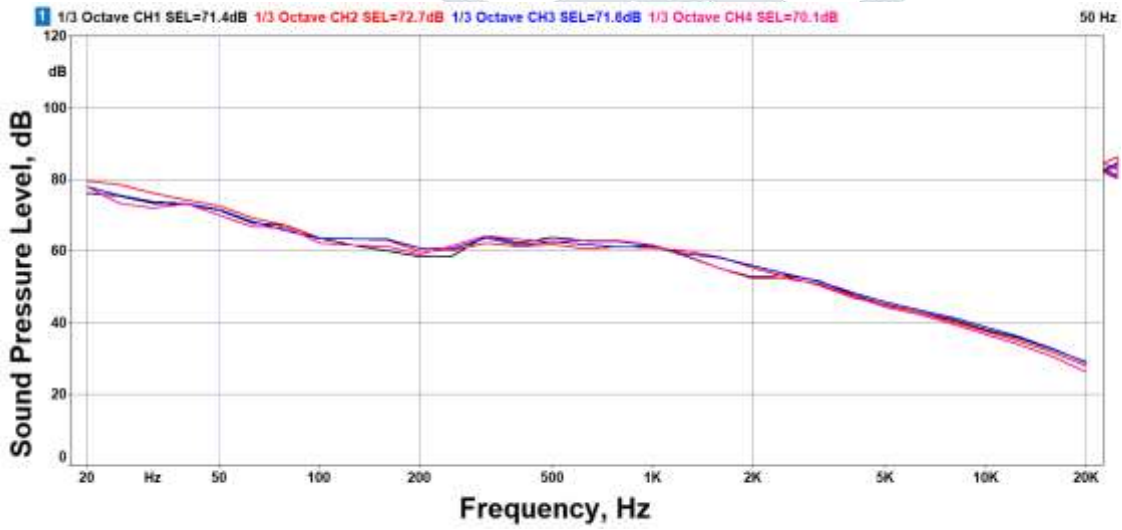

Figure 3: 1/3rd Octave plot of Gen Set with Resonant AMM on top

V. Comparison of Averaged Sound Pressure Level of All Four Stages:

The average sound pressure level is calculated by averaging the pressures obtained at all the locations mentioned on each side as shown in Figure 1. The average sound pressure level in 1/3rd octaves is plotted and compared for front side, back side and near muffler in order to verify graphically the results reported in Table 1. Figure 5 shows the 1/3rd octave plot comparison for all the four cases and it is observed that Manufacturers casing is showing some effect on higher frequency noise reduction and polyimide alone is also performing very well at higher frequency band because of lower wavelengths and of all resonant type acoustic metamaterial is showing uniform performance in all the bands which is the reason for its higher noise reduction. A similar behavior is seen on backside of the Gen Set as well but there is slight increase in SPL at few low frequency bands 200, 315, 400 and 500 Hz. This can be due to the effect of external wall reflections.

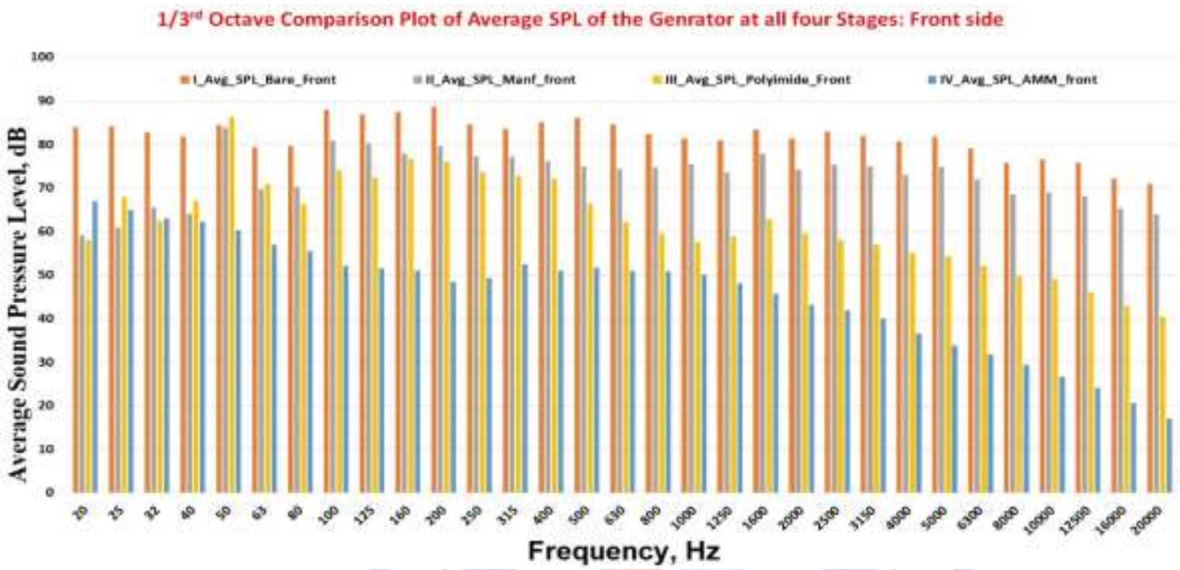

Figure 4: Averaged Sound Pressure Level (dB) comparison on front side

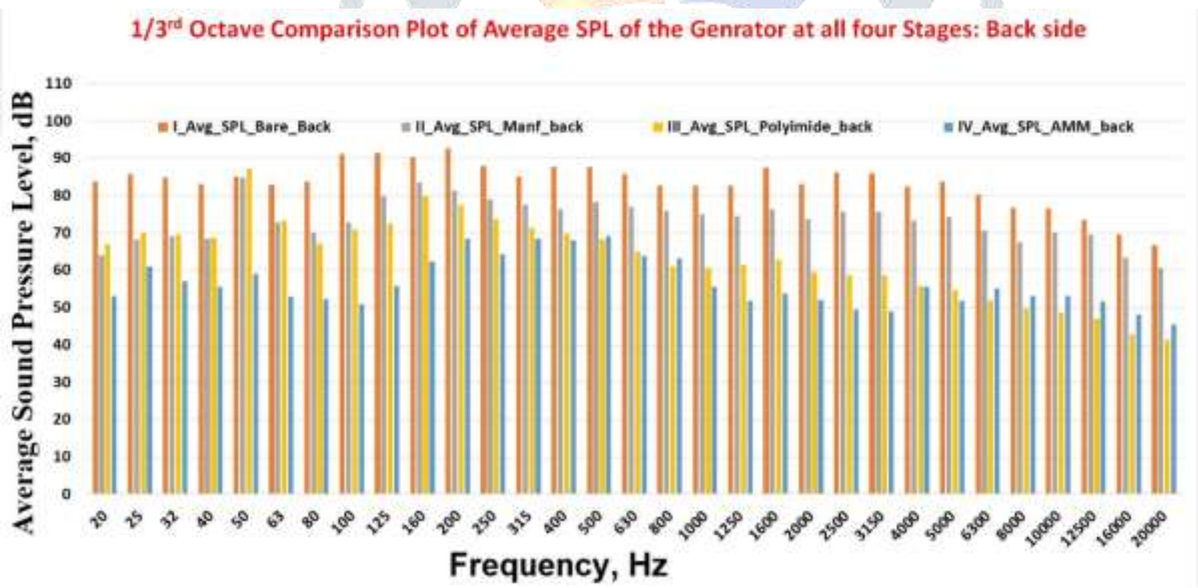

Figure 5: Averaged Sound Pressure Level (dB) comparison on backside

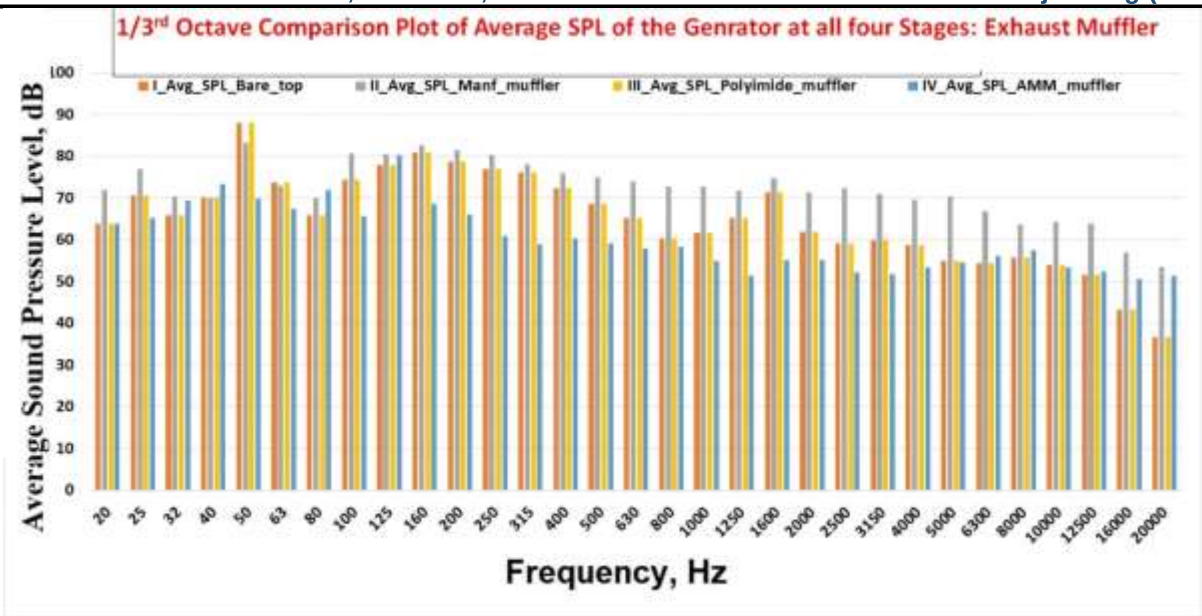

FIGURE 6: AVERAGED SOUND PRESSURE LEVEL (DB) COMPARISON AT EXHAUST MUFFLER

Finally, from Figure 6 it is observed that the noise reduction is severely affected due to the poor performance of the exhaust muffler. Thus, from the present analysis it is confirmed that the broadband noise reduction can greatly be enhanced by the use of resonant acoustic metamaterials in place of convectional sound proofing material.

VI. Comparison of Averaged Sound Pressure Level of All Four Stages:

This study is performed to demonstrate the performance of resonant type acoustic metamaterial over conventional sound absorbing material for broadband noise reduction.

It is established from the present study that we can enhance the broadband noise reduction by the use of Polyimide foam treated with detuned Helmholtz resonators and Quarter wave tubes. Here, resonators and QW tubes helps to reduce the low and medium frequency noise and Polyimide helps to reduce high frequency noise. The AMM is so designed that the split modes developed when tuned HRs are coupled to any acoustic cavity is also addressed by introducing detuned HRs and QW Tubes tuned to these virtual split modes. Further emphasis has been made on what type of low and medium frequency modes to be selected for better noise reduction. As seen from Table 1 & Figures 4-7 it is proved that resonant type AMM are one of the best solutions for any type of cavity noise reduction. The sound absorbing material for high frequency noise reduction can be selected based on the application of its need.

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