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ANALYSIS OF A LOW FREQUENCY MUFFLER BASED ON THE ACOUSTIC BLACK HOLE EFFECT

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1. Introduction

In order to keep up with the regulatory compliance norms, there have been continued efforts to install and maintain quieter machinery. In several such instances, the industrial mufflers and silencers have been the target areas of amelioration. Essentially, a muffler (or silencer, often used interchangeably) is a low pass acoustic filter[1], used to attenuate noise levels from machinery and other noisy sources. Besides automotive and aviation sectors, the other applications where components of low frequency noise are considered disturbing, include, industrial plants, wind turbines, blowers and compressors, ducts and vents, HVAC systems, high-speed trains and even exposure to loud music. To achieve low overall noise exposures from these sources, machine designers, fabricators and operators have developed hybrid mufflers, unlike the conventional classification; make use of both absorptive and reactive design elements. Managing the noise by absorption at source and/or receiver ends, in combination with manipulating its flow along the path, the technological advancement for modern-day mufflers seems challenging and intriguing.

Amid the considerable amount of efforts for developing effective absorption and noise control techniques, the concept of Acoustic Black Hole (ABH), as an effect, has gained popularity. ABH based structures rely on the principle of impedance matching and, in principle, can achieve a total absorption of incident sound. Till date, ABH effect has been applied to several configurations such as, for waves travelling over surfaces such as plates, wedges, beams, across cylinders and more recently, through terminating tubular structures. ABH based studies[2] carried out so far encompass single and multi-dimensional structures, analyzed by not only analytical and numerical but also experimental techniques to achieve at least modest reductions in noise, pressure, size and cost, as applicable to above mentioned sources of noise.

It has been, probably for the first time, theoretically demonstrated by Mironov and Pislyakov[3] that ABH effect can be applied to a noisy medium through a terminating structure, rather than the surface. The paper has presented that a total absorption of sound can be achieved in the tube with quasi-periodic ribbed internal structures, whose radii decreased to zero with the structure's termination, i.e. devoid the use of absorbing materials. To complement this study, the only experimental investigation of the ABH based sound absorption through a terminating structure, considering both the exclusion and inclusion of absorbing materials have been conducted by A. Azbaid, et al[4].

In the present paper, Mironov's ABH model has been extended and modified to deal with an open chamber design and accounting for the presence of losses. The muffling section, embodying the open expansion chamber, is such that it comprises of a narrow tube of axisymmetric waveguide with constant