

Realization of Ground Effects on Snowmobile Pass-by Noise Testing

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ABSTRACT

Noise concerns regarding snowmobiles have increased in the recent past. Current standards, such as SAE J192 are used as guidelines for government agencies and manufacturers to regulate noise emissions for all manufactured snowmobiles. Unfortunately, the test standards available today produce results with variability that is much higher than desired. The most significant contributor to the variation in noise measurements is the test surface. The test surfaces can either be snow or grass and affects the measurement in two very distinct ways: sound propagation from the source to the receiver and the operational behavior of the snowmobile. Data is presented for a known sound pressure speaker source and different snowmobiles on various test days and test surfaces. Relationships are shown between the behavior of the sound propagation and track interaction to the ground with the pass-by noise measurements.

INTRODUCTION

Noise testing of snowmobiles has been of increasing interest with many government agencies around the world. Although there are many methods of testing outdoor machinery, there are many aspects of snowmobile operation and design that create significant difficulty with making an easily regulated noise standard. Snowmobiles are recreational tracked vehicles that are primarily used on snow surfaces which are typically groomed trails or off-trail powder. Vehicle tracks are built to be optimized for the type of riding; shorter tracks with smaller lugs are best suited for groomed trail riding, and longer tracks with larger lugs are best suited for off-trail powder riding. Snowmobiles have a continuously

variable transmission that connects either a 2-stroke or a 4-stroke engine to the track's drive axle.

Current noise standards, like SAE J192 [1] allow for multiple test surfaces: snow and grass. Snow surfaces offer similar conditions to the typical operating condition for snowmobiles. Grass surfaces allow manufacturers and third party testing organizations to test during times of the year when it becomes difficult to find (or expensive to travel to) snow surfaces. SAE J192 is a full acceleration pass-by noise test with a course layout as described in Figure 1.

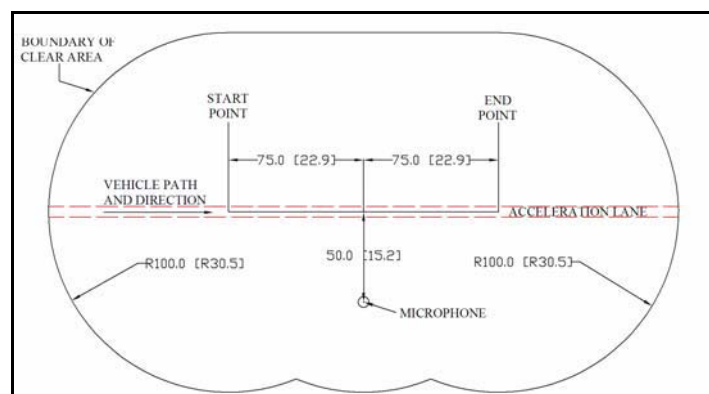


Figure 1: SAE J192 Course Layout - Units: ft [m]

The current standard, at the time of this writing, only lays out a general description of an allowable test surface for both snow and grass. Current research has determined that there are two major aspects of the test conditions that affect its repeatability. One major aspect is the way that the track interacts with the ground, and the other

major aspect is how the sound propagates from the source to the receiver. Both aspects are dependent on the ground conditions. Testing was conducted over two winter seasons and one summer season using the current SAE J192 description, and the results indicate that experimental data falls outside the publishes variability allowance.

Previous research [2] evaluated the repeatability of determining the sound power of snowmobiles using a course described in both SAE [3] and ISO [4] standards. Snowmobiles were tested by both constant speed and acceleration methods. The research suggested that the environmental effects could be accounted for by evaluating a speaker sound source, but there was no improvement in the variability of measured snowmobile response. The research suggested that more data was needed to better understand the track interaction with the ground and remarked the differences between snow and grass ground conditions. Research presented in this paper furthers the understanding of these factors for the pass-by noise testing of snowmobiles.

TESTING THE ENVIRONMENT

Understanding the sound propagation behavior at the test course is a key component to understanding the variability in the snowmobile pass-by noise results. A brief review of outdoor sound propagation theory is covered to anticipate the experimental results. A known sound pressure speaker source was used each test day to experimentally determine the acoustic behavior of the test course. In addition to testing a known source, other environmental and ground conditions were measured and recorded.

OUTDOOR SOUND PROPAGATION THEORY OVERVIEW

There are many phenomena in an outdoor environment that can affect sound propagation from a source to a receiver. Atmospheric absorption, ground impedance, wind, thermal inversions and changes to air density and speed of sound all play a factor in the response measured at a receiver location. A general sound field geometry is shown in Figure 2 having both a source and receiver above the ground surface.

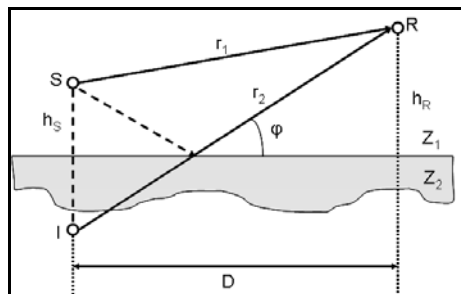


Figure 2: Geometry of Sound Propagation Over Ground

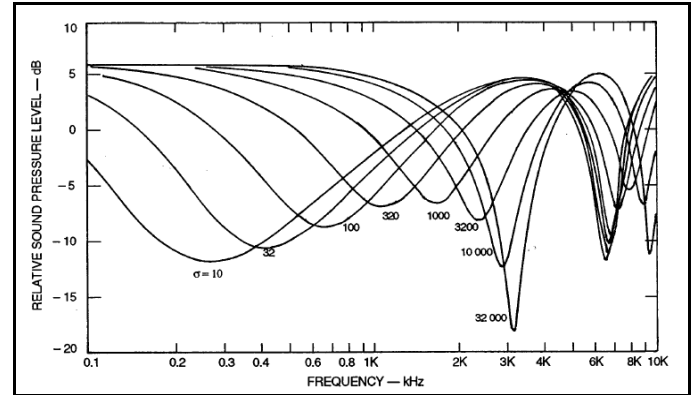
Ground impedance is the most significant factor to outdoor sound propagation. The air (Z_1) and ground (Z_2) impedances determine how a sound wave interacts with the ground and affects the reflective wave energy. The total response at the receiver (R) from the source (S) is a summation of the energy transmitted along the direct path (r_1) and transmitted along the reflective path (r_2). Sound waves from the two directions interact either a constructive or destructive manner as a function of the source height (h_s), receiver height (h_r), ground impedance and frequency. The geometry and impedance determine the phase difference between the two paths which determines how the sound waves will interact with each other.

A parameter that has been used to characterize ground impedance is flow resistivity [5-7]. An overview of different ground surface types and their corresponding flow resistivity values is provided in Table 1. Low flow resistivity values are associated with acoustically soft surfaces where high flow resistivity values are associated with acoustically hard surfaces. Although the test surfaces for snowmobiles are at the lower end for flow resistivity values, a more complete list is included to establish a physical reference.

Table 1: Flow Resistivity Data for Ground Surfaces

Types of Ground	Effective Flow Resistivity kPa(s/m ²)	
	Range	Average
Concrete, painted	200,000	200,000
Concrete, various finishes	30,000–100,000	65,000
Asphalt, old, sealed with dust	25,000–30,000	27,000
Asphalt, new, depends on particle sizes	5,000-15,000	10,000
Dirt, exposed, rain-packed	4,000-8,000	6,000
Dirt, roadside with < 4 inch rocks	300-800	550
Soil, various types	40-906	317
Grass lawn or grass field	125-300	200
Clay, dry	92-168	130
Grass field, 16.5% moisture content	75	75
Forrest floor (Pine/Hemlock)	20-80	50
Grass field, 11.9% moisture content	41	41
Snow, various types	1.3-50	29

With the flow resistivity determined for a given ground condition, the sound field can be predicted in terms of sound pressure level (SPL). The data shown in Figure 3 shows the predicted spectra for a source height of 0.31 meters, a receiver height of 1.22 meters and a horizontal separation of 15.2 meters (these distances are very common to many different outdoor vehicle testing in the United States). The SPL values are compared with a reference location at 1 meter away from the source at the source height.

**Figure 3: Predicted Spectra for Various Values of Flow Resistivity (reprinted with permission) [6]**

Considering only flow resistivity as a parameter to ground impedance, it is apparent that there are many frequency regions that will be affected greatly. Specific to the snow and grass surfaces used for testing snowmobiles, there is a significant difference in the sound propagation behavior in frequencies below 1000 Hz. As it will be discussed in a later section, this lower frequency region (<1000 Hz) is a region where most sound energy is generated by snowmobiles.

EXPERIMENTAL APPROACH

Two methods of data collection were used to quantify the acoustic environment of the test location. Ground and environmental conditions were recorded for each test day in addition to using a known omnidirectional sound pressure speaker source. Recorded environment and ground conditions are listed in Table 2.

Table 2: Recorded Ground and Environmental Conditions

Winter Testing (unit)	Summer Testing (unit)
Air Temperature (degF)	Air Temperature (degF)
Barometric Pressure (inHg)	Barometric Pressure (inHg)
Wind Speed (mph)	Wind Speed (mph)
Wind Direction (deg)	Wind Direction (deg)
Snow Hardness (Smither's Hardness)	Ground Hardness (lbs)
Snow Depth (inches)	Grass Height (inches)

The speaker was placed in a static location at the center of the test course with its response measured at a distance specified by SAE J192. Experimental data was