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Using the SmarTek Acoustic Sensor-Version 1 (SAS-1) As a Vehicle Direction Indicator

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Introduction

The SmarTek Systems Acoustic Sensor - Version 1 (SAS-1) is a novel multi-lane traffic monitoring system based on detecting the acoustic signals motor vehicles create and radiate during operation. The SAS-1 is a non-contact, passive acoustic (listen only) sensor and is mounted on existing overhead or roadside structures such as light poles, sign bridges, and overpasses. It is completely non-intrusive to the highway or to the travelers using the highway. The SAS-1 is very compact and lightweight. It is designed to be quickly and easily installed on existing highway structures. No lane closures are needed for a typical installation on a roadside structure using a bucket truck. Reliability for the adverse highway environment is designed in to minimize or eliminate any periodic maintenance requirements.

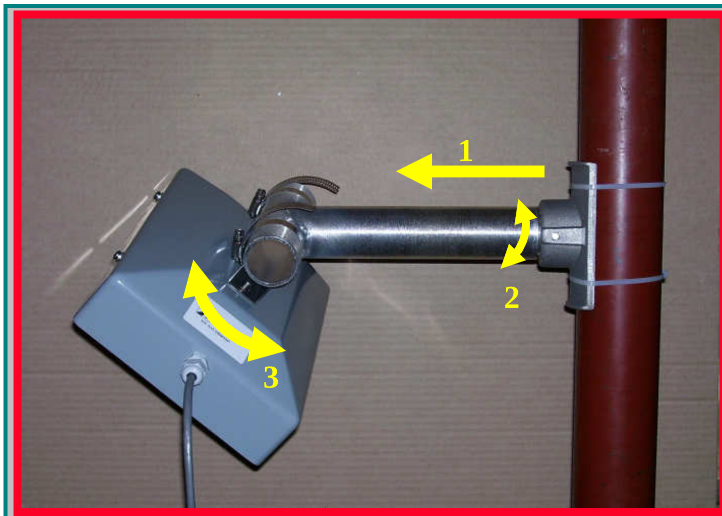


Figure 1 SAS-1 and Mounting Tube

As a passive sensor that does not radiate a signal, the SAS-1 requires very little power to operate. This coupled with a wireless "home run" option makes the SAS-1 very suitable for completely autonomous installation and operation. A small solar panel keeps an associated battery charged, eliminating the need for a hard wired "home run" cable, associated conduit, and installation labor. Using the SAS-1 with solar power and wireless communication also minimizes weather related project schedule perturbation since there is no need to dig or trench the ground for cables or to cut pavement for loops.

The SAS-1 utilizes advanced signal and spatial processing to provide adaptive interference cancellation and high resolution multi-lane or multi-zone traffic monitoring, including shoulder activity. This advanced processing minimizes or eliminates false vehicle detections caused by out of lane or off road noise. The SAS-1 "acoustically images" the highway traffic across the entire roadway, thereby providing the end user with significant flexibility to electronically position each detection zone and set each detection zone's size. This capability eliminates the necessity of precise mechanical "pointing" of the sensor to a detection zone position during install. Electronic detection zone positioning and repositioning (if lanes are moved) is accomplished using SmarTek Systems provided Windows based software. The easy to use "SAS Monitor and Setup" software displays the position of every vehicle in real time as the vehicle passes the sensor station. The easy to use "SAS Monitor and Setup" software displays the position of every vehicle in real time as the vehicle passes the sensor station. With point and click controls, the end user electronically sets each detection zone position relative to the mechanical sensor orientation after the sensor has been permanently "locked down".

Vehicle Direction Sensing using Loops

An important area of concern relative to highway safety is the occurrence or drivers going the wrong way on one-way streets, highway mainline lanes, or highway entry or exit ramps. Along with significant signing, various monitoring approaches have been tried and implemented to provide immediate detection of vehicles going the **"Wrong Way"**. To date, systems using magnetic induction loops represent the most common solution for "Wrong Way" detection (Figure 2). Two or more loops are placed in the roadway as shown in Figure 2. Relative to the correct direction of travel, loop #1 is the upstream vehicle detection sensor and loop # 2 is the downstream vehicle detection sensor. In the presence of traffic, vehicle detection at loop # 1 followed by detection at loop #2 indicates the correct direction of travel by the detected vehicle. Vehicle detection at loop #2 followed by detection at loop #1 indicates the incorrect direction of travel by the detected vehicle. When properly installed and maintained, the loop-based system performance should be reasonable.

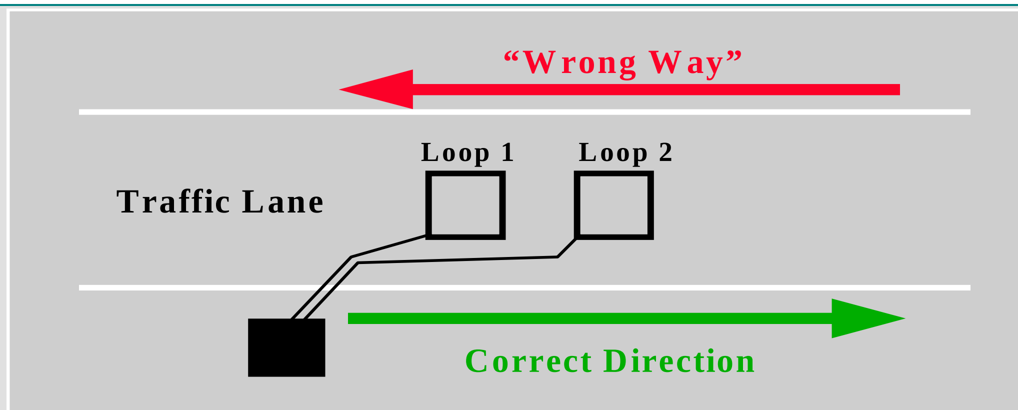


Figure 2 Loop-Based "Wrong Way" Detection

While the use of multiple loops for "wrong way" detection is technically reasonable, from a practical and fiscal point of view, their use come with many well known problems. Loops are embedded into the pavement and hence require lane closure for installation, maintenance, or replacement. They may not function properly in the vicinity of barriers or other heavy metal structures used for access control. Because of various mechanical stresses and installation inconsistencies, loops have an unacceptable failure rate which leads to increased life cycle costs. Loop detection zone size and sensitivity sometimes allow missed detections when vehicles do not travel directly over the loop or only partially travel over the loop. This is particularly an issue for freeway ramp applications where vehicles routinely travel on the shoulder of curved ramps and thus completely miss the loop detectors located in the center of the ramp lane.

Vehicle Direction Sensing using SAS-1

The SmarTek Acoustic Sensor (SAS-1) is absolutely suitable for "Wrong Way" detection of vehicle. The SAS-1 is designed to operate and provide effective and accurate vehicle presence detection for vehicles passing the sensor station at any reasonable (and allowable) speed from very slow (or stationary) to high speed. There is no inherent upper speed limitation for highway traffic because faster moving vehicles create increased levels of acoustic energy making them easier to detect. Because the SAS-1 is based on passive acoustic detection of motor vehicles, there is virtually no loss of detection performance due to variation in weather or environmental conditions or visibility conditions. For a typical "Wrong Way" detection system installation as shown in Figure 3, the maximum number of zones monitored by the SAS-1 is set at five(5). Inherent in this configuration, is the capability for the SAS-1 to measure per vehicle speed. This capability is not included as a standard sensor output at this time, but is calculated in a separate microcontroller and relay interface for alarms and notification. For the configuration shown in Figure 3, a vehicle traveling in the correct direction will be detected in the SAS-1 detection zones in the following sequential order: zone 1, then 2, then 3, then 4, and finally zone 5. A vehicle traveling the "Wrong Way" will be detected in the SAS-1 detection zones in the opposite sequential order as follows: zone 5, then 4, then 3, then 2, and finally zone 1. Obviously, the spacing of the zones will determine the response time for the "Wrong Way" detection. The number of zones used is selectable, however, using more than two (2) is recommended to minimize the chance of false detections.

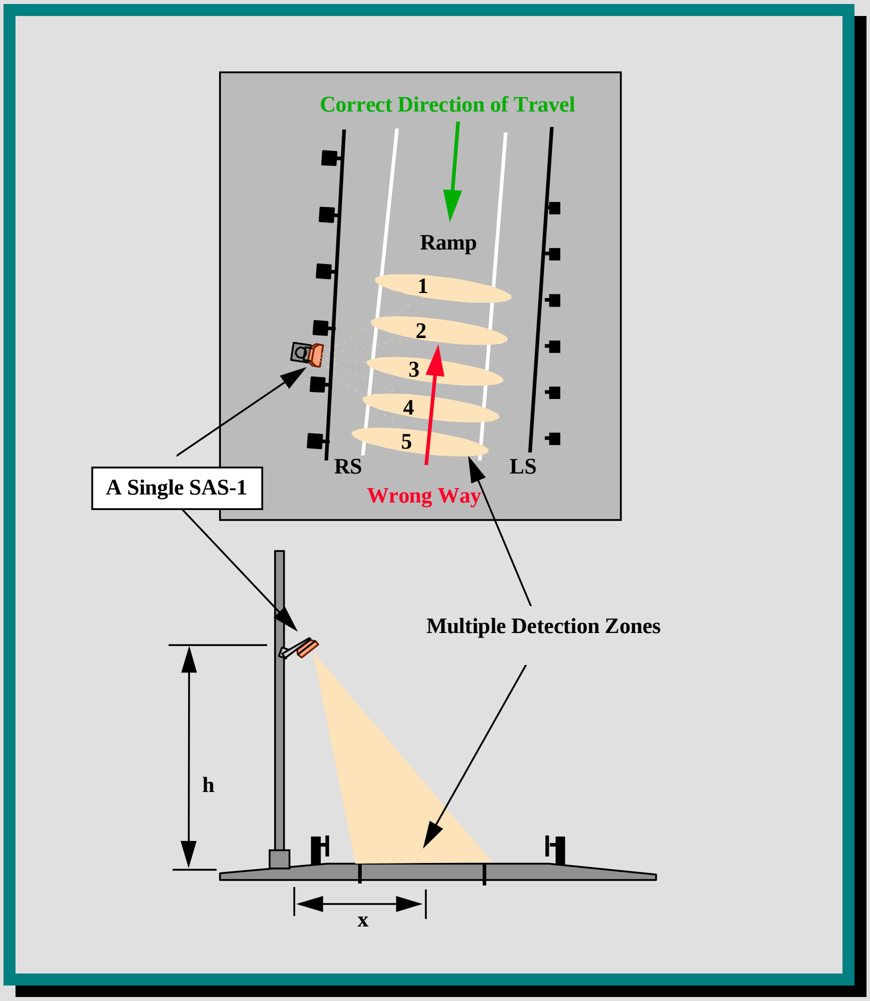
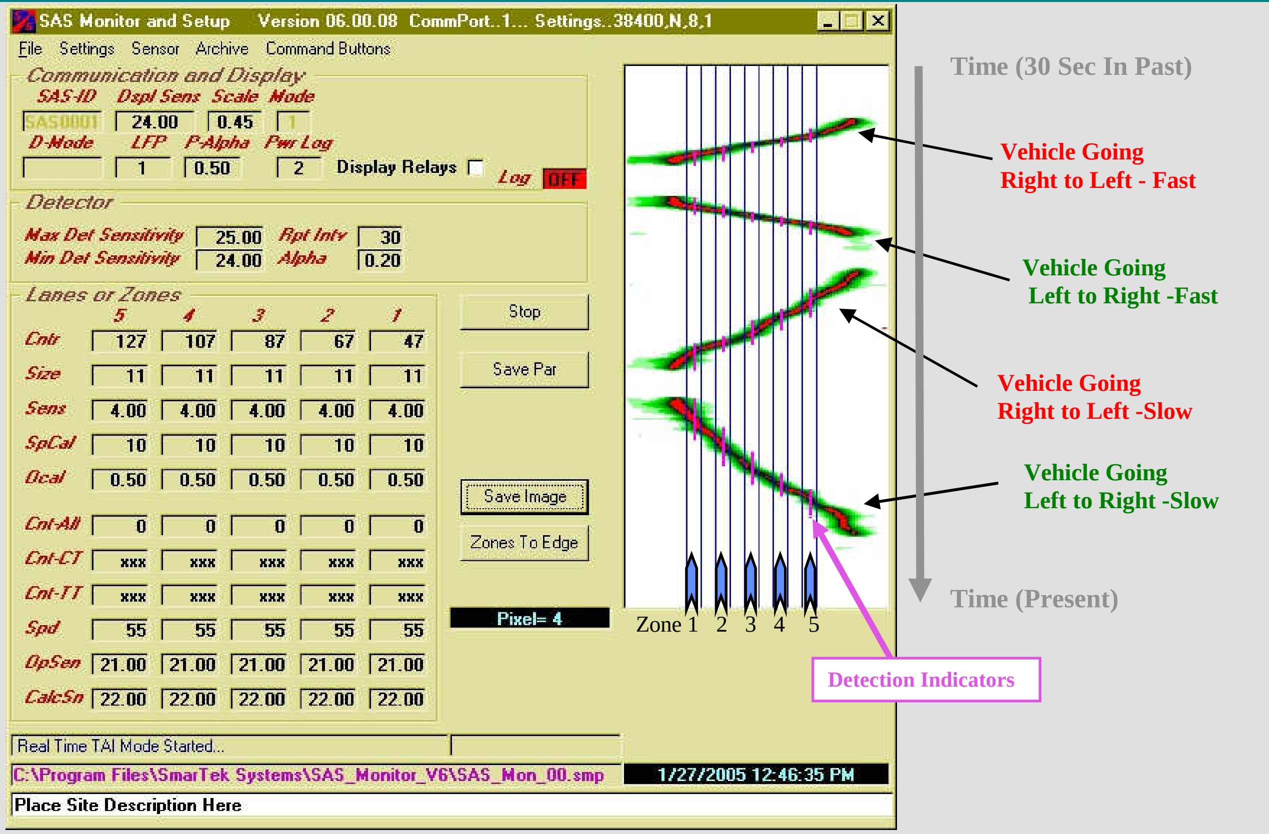


Figure 3 SAS-1 "Wrong Way" Detection Configuration

Using the easy to install side mount configuration, the SAS-1 provides a "Wrong Way" detection capability equivalent to a loop based system using up to five (5) loops.

Example -Using SAS-1 to Determine Direction of Travel

The real acoustic signal display in Figure 4 was captured from the SAS Monitor and Setup Program. The display shows real acoustic signals as light green tracks and the corresponding vehicle detection indicators as magenta markers at the center of each detection zone. Time increases from top to bottom on the display. Therefore, as vehicles pass by the sensor, their signal will show up on the left and move to the right on the display. Also, depending on whether a vehicle moves from "left to right" or "right to left" as referenced from behind the SAS-1, the signal track will move from "bottom to top" or "top to bottom" respectively. Vehicles passing by the SAS-1 from "left to right" are moving the correct way. Vehicles passing by the SAS-1from "right to left" are moving the



	5	4	3	2	1
Cntr	127	107	87	67	47
Size	11	11	11	11	11
Sens	4.00	4.00	4.00	4.00	4.00
SpCal	10	10	10	10	10
Dcal	0.50	0.50	0.50	0.50	0.50
Cnt-All	0	0	0	0	0
Cnt-CT	xxx	xxx	xxx	xxx	xxx
Cnt-TT	xxx	xxx	xxx	xxx	xxx
Spd	55	55	55	55	55
OpSen	21.00	21.00	21.00	21.00	21.00
CalcSn	22.00	22.00	22.00	22.00	22.00

Figure 4 SAS-1 Real Signal "Wrong Way" Example

"Wrong Way". Note that the signal track (light green) for the first and third vehicles move from upper right toward lower left which indicates "right to left" vehicle movement. The second and fourth signal tracks move from the upper left toward the lower right which indicates "left to right" vehicle movement. Note closely the magenta markers at the center of each detection zone. These markers provide a visual indication of what vehicle presence relay is active and when it is inactive. For the second and fourth vehicles, the vehicle presence relays (magenta markers) turn on in the following order: zone 1, then 2, then 3, then 4, and finally zone 5, which clearly and unambiguously indicates the direction of travel as being "left to right". For the first and third vehicles, the vehicle presence relays (magenta markers) turn on in the opposite order: zone 5, then 4, then 3, then 2, and finally zone 1, which indicates "right to left" as the direction of travel.

Example - Using SAS-1 to Measure Per Vehicle Speed

Consider again the real acoustic signals shown in the display of Figure 4. The previous discussion illustrated how the direction of the acoustic track (light green) and hence the order that the vehicle presence relays become active indicates direction of travel (lower left toward upper right or upper left to lower right). If one measures the actual value of the slope of the acoustic track as it passes the SAS-1, then per vehicle speed can be accurately determined from the value of the slope. A fast moving vehicle has a small slope (nearer horizontal on the display) while a slow moving vehicle has a large slope (nearer vertical on the display). Note that just as in-pavement loops are spaced in the up/down road direction, each detection zone for SAS-1 corresponds to a physical location in the up/down road direction. Therefore, measuring the time between SAS-1 zone detections (relays become active) is the same as measuring the slope of the acoustic signal track and corresponds exactly to measuring time between loop detections in a double loop speed trap. One major difference, however, is that for the SAS-1 approach, there are four (4) time measures (between zone 1 and 2, between zone 2 and 3, etc.) to use for averaging instead of just one. This will result in a more accurate per vehicle speed measurement.

Signal Interfaces

The SAS-1 provides for several different interfaces depending on the communication link and the cabinet controller interface desired. The standard SAS-1 output message provides traffic flow measurements of vehicle volume, lane occupancy, and average speed for each monitored zone (3 lanes and 2 shoulders) for a specified update period (i.e. 20 sec, 30 sec, 1 min, etc). Vehicle presence relays or a "Wrong Way" asynchronous message can be provided. The vehicle presence relay option requires a SAS-1 Bit Serial to Parallel Interface in the roadside cabinet. The SAS-1 supports the following electrical communication interfaces:

1) RS-485 (full duplex)(Standard)......................Hard Wired Home Run (up to 1500 feet)
2) RS-232 (Optional)..Hard Wired Home Run (up to 100 feet)
3) RS-232 (Optional)..................................Wireless Link (range depends on RF devices used)

Power

The SAS-1 re-regulates the supply voltage thus compensating for voltage drops and fluctuations caused by long home run cables:

1) Supply Voltage at the Sensor............................7 to 24 VDC
2) Required Power.......................................Less than 1.5 watts

Physical

The SAS-1 is a very compact multi-lane highway monitoring sensor. Superior spatial resolution is achieved by advanced processing rather than physical aperture, thereby resulting in a very small sensor footprint (Figure 1):

1) Dimensions...............................12 inches long x 8 inches wide x 5 inches deep
2) Weight......................................Less than 2.5 lbs.
3) Material/Finish..........................Aluminum/Enamel/Stainless Steel Fasteners
4) Mounting Approach..................2 inch Diameter Aluminum Tube/Stainless Steel Bands
5) Operating Temperature..............-20 Deg C to 75 Deg C
6) Humidity...................................5% to 100%
7) Shock..NEMA TS2-2.1.10
8) Vibration....................................NEMA TS2-2.1.9

Installation

The SAS-1 provides a great deal of flexibility relative to installation. Its compact size and modest weight make installation easy for a single installer using a bucket truck. Off the shelf, low cost mounting brackets can be utilized. Mounting brackets should allow for coarse mechanical positioning so that the sensor face can be oriented to correspond to the operating mode (Multi-Lane monitoring or Wrong Way monitoring) Powering the sensor and using the SAS-1 Monitor and Setup program on a PC Laptop makes the SAS-1 installation and pointing easy and quick. Monitoring the real time display while mechanically orienting the sensor removes any guesswork relative to the SAS-1installation. After the SAS-1 is mechanically oriented and locked down, the position and size of each detection zone (up to 5 in cross road or the up/down road direction) can then be electronically adjusted using the SAS-1 Monitor and Setup program to precisely match the detection zone configuration to the specific traffic flow situation.

1) Height Above Pavement.......................................20 to 40 feet
2) Horizontal Distance to First Detection Zone..........0 to 40 feet (or greater for "Wrong Way" detector)
3) Coarse SAS-1 Orientation...................Mechanical with SAS-1 Monitor and Setup Software
4) Precise Detection Zone Adjustment.......Electronic with SAS-1 Monitor and Setup Software

Standard List of Equipment for SAS-1 Wrong Way Detection System:

1 SAS-1 Single Lane wrong way detection system sensor
1 SAS-Mounting Assembly
1 SAS-CT Cabinet Termination, shelf mount
1 SAS-CT to USI2k, 12 VDC Power supply (120 AC to 12 VDC)
1 SAS-1 JB Junction Box (Large) with Surge protection
1 SAS-CT2PC Cable for set up and SAS-MON SW
1 STS-USI2K External system interface and controller
w/Programming for Wrong Way Detection
1 SAS-PRM, power relay and DC Distribution

Optional Components
1 STS Device Server for network access and monitoring
1 Alarm siren/strobe light combination with 12 VDC power supply
1 External NEMA 3R enclosure for system interface and power supply
TBD Homerun Wiring

Installation Geometry Notes:

Install such that the sensor has a clear line of sight to the single lane of passing traffic. For multiple lane applications, use the SVS-1 Video based detection system. Place barriers or bollards as necessary to implement single lane of flow in at a consistent speed as possible, or locate sensor as necessary around previously placed barriers as necessary.