A COMPARATIVE STUDY BETWEEN GMLAN SPEED AND GPS REPORTED VEHICLE SPEED BY VEHICLE MANEUVER

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ABSTRACT

Some GM (General Motors) vehicles are using a GMLAN (General Motors Local Area Network) communication protocol for control and diagnostics. The airbag control module uses vehicle speed information from the GMLAN to record the vehicle speed as pre-crash information. In order to use the vehicle speed information for crash reconstruction purposes, it helps to be able to understand the accuracy of the data. The actual vehicle speed is not expected to be the same as the GMLAN indicated speed in some situations like a spin or if there is hard braking. This paper compares the actual vehicle speed and vehicle speed information during specific vehicle maneuvers. Actual vehicle speed is calculated from a GPS sensor, while GMLAN vehicle speed is calculated from transmission output sensor by the Engine control module (ECM). Vehicle maneuvers defined as Mode #1, Mode #2, Mode #3. The Mode #1 maneuver simulates wheel lock-up and skidding during Hard-braking at a specific speed. The Mode #2 maneuver simulates a 90degree turn using a J-turn maneuver at a specific speed. The Mode#3 maneuver simulates a 180 degree turn using a spin type of maneuver at a specific speed. The study then compares the GMLAN speed and GPS speed to see what speed difference exists between them. The results of this paper are applicable to GM vehicles only. This paper catalogs the performance and limitations of two vehicles as useful reference for crash reconstructions where there is a need to understand the speed indicated in the pre-crash section of the SDM data.

INTRODUCTION

Vehicular crash reconstruction is used to determine how a crash happened. An understanding of the vehicle status during the crash is important factor for the crash reconstruction. At General Motors (GM) the internal term for an airbag control module is Sensing and Diagnostic Module (SDM). The SDM controls the crash sensing and deployable restraints. The SDM also records crash and deployment information when a deployment level crash occurs as well as for some non-deployment events. Also, the SDM records a limited amount of vehicle status information as pre-crash information. This pre-crash information could be important data to understand. At GM, the internal term for the recording function is Event Data Recorder(EDR). The SDM records vehicle status information for a short period of time prior to and during the crash. Such information as accelerator pedal position, brake switch circuit status, engine speed, throttle Position, and vehicle speed are recorded. This paper focused on vehicle speed information. When a SDM records vehicle speed in the EDR, the SDM receives vehicle speed data from the ECM (Engine Control Module) through the GMLAN bus which is one of the electric communication protocols of GM vehicles. Vehicle speed represents longitudinal speed of vehicle for the tire rotation because the ECM calculates vehicle speed from transmission output sensor. So, if vehicle is skidding due to wheel lock-up during hard braking or skidding in a lateral direction, the vehicle speed may not be same as vehicle longitudinal movement.

Reconstruction

Vehicle speed can be calculated through physical evidence on the roadway such as brake marks, skid marks or other clues at the incident scene for crash reconstruction. But sometimes it may be hard to get this information from the incident scene due to scene conditions erasing skid marks and other evidence. In the case of ABS braking, the witness marks are faint to begin with and can be erased, misinterpreted, or be nonexistent for the entire length of applied braking. In this case EDR data becomes an important information source for crash reconstruction. Accident reconstructionists use the EDR as another piece of information to verify their calculations and

assumptions. Understanding the limitations of the pre-crash data is important to accident reconstruction. Moreover, understanding the accuracy of this information and how the data recorded is more important to improve the accuracy of the crash reconstruction effort.

Pre-crash data of EDR

The SDM records to the EDR when the record condition is met. For example, if delta velocity is over 8km/h or when safety protection devices like a belt pre-tensioner or an airbag is deployed EDR recorded data includes parameters such as restraint system data and vehicle data. Restraint system data such as, seat belt status, airbag status, deployment status, SDM status, DTC (Diagnostic Trouble Code), etc., is recorded(Table 1). Vehicle data - such as accelerator pedal position, brake switch circuit status, engine speed, throttle position, vehicle speed, etc. (Table 2), is recorded for a brief period of time prior to the crash.

Table1. Example of restraint system data

Driver 1st Stage Deployment Loop Commanded	Yes
Passenger 1st Stage Deployment Loop Commanded	Yes
Driver 2nd Stage Deployment Loop Commanded	No
Passenger 2nd Stage Deployment Loop Commanded	No
Driver Pretensioner Deployment Loop #1 Commanded	Yes
Passenger Pretensioner Deployment Loop #1 Commanded	Yes
Driver Pretensioner Deployment Loop #2 Commanded (If Equipped)	Yes
Passenger Pretensioner Deployment Loop #2 Commanded (If Equipped)	Yes
Driver Thorax Loop Commanded (If Equipped)	No
Passenger Thorax Loop Commanded (If Equipped)	No
Driver Row 2 Thorax Loop Commanded (If Equipped)	No
Passenger Row 2 Thorax Loop Commanded (If Equipped)	No
Driver Row 1 Roof Rail/Head Curtain Loop Commanded (If Equipped)	No
Passenger Row 1 Roof Rail/Head Curtain Loop Commanded (If Equipped)	No
Driver Row 2 Roof Rail/Head Curtain Loop Commanded (If Equipped)	No
Passenger Row 2 Roof Rail/Head Curtain Loop Commanded (If Equipped)	No
Driver Row 3 Roof Rail/Head Curtain Loop Commanded (If Equipped)	No
Passenger Row 3 Roof Rail/Head Curtain Loop Commanded (If Equipped)	No
Driver Knee Deployment Loop Commanded (If Equipped)	No
Passenger Knee Deployment Loop Commanded (If Equipped)	No
Driver Row 2 Pretensioner Deployment Loop Commanded (If Equipped)	No
Passenger Row 2 Pretensioner Deployment Loop Commanded (If Equipped)	No
Center Row 2 Pretensioner Deployment Loop Commanded (If Equipped)	No
Battery Cutoff Loop Commanded (If Equipped)	No
Driver Roll Bar Loop Commanded (If Equipped)	No
Passenger Roll Bar Loop Commanded (If Equipped)	No
Steering Column Energy Absorbing Loop Commanded (If Equipped)	No
Driver Head Rest Loop Commanded (If Equipped)	No
Passenger Head Rest Loop Commanded (If Equipped)	No
Driver Row 2 Head Rest Loop Commanded (If Equipped)	No
Passenger Row 2 Head Rest Loop Commanded (If Equipped)	No
Center Row 2 Head Rest Loop Commanded (If Equipped)	No
High Voltage Battery Cutoff Loop Commanded (If Equipped)	No

Table2. Example of vehicle data

Seat Belt Status	
Passenger Seatbelt Buckle Switch	*Data Not Available*
Driver Seatbelt Buckle Switch	*Buckled*

Brake Pedal Status	
Brake Pedal Status Current	*OFF*
Brake Pedal Status 0.5 seconds prior	*OFF*
Brake Pedal Status 1.0 seconds prior	*OFF*
Brake Pedal Status 1.5 seconds prior	*OFF*
Brake Pedal Status 2.0 seconds prior	*OFF*

Vehicle Speed Data	
Vehicle Speed Current	*24km/h*
Vehicle Speed 0.5 seconds prior to current	*22km/h*
Vehicle Speed 1.0 seconds prior to current	*20km/h*
Vehicle Speed 1.5 seconds prior to current	*19km/h*
Vehicle Speed 2.0 seconds prior to current	*17km/h*

Among the above vehicle status information, vehicle speed is obtained from the GMLAN communication bus. Vehicle speed is calculated by the ECM from the signal off of the transmission output sensor. This vehicle speed shows the longitudinal velocity or speed of vehicle along the wheel rotation. The BCM receives vehicle speed from the ECM and then transmits it to the GMLAN communication bus. The ECM and BCM each have a 100ms time interval to transmit vehicle speed information. For this reason, vehicle speed information on the GMLAN has time lag up to a 200ms.

VEHICLE SPEED MEASURING AND ANALYSIS USING VEHICLE MANEUVER TEST

Test schematic

Vehicle testing was conducted to get speed data using a Chevrolet CRUZE with ABS (Anti-lock Brake System) and an AVEO without ABS. There were three test modes. Mode #1 intended to simulate hard braking on a dry asphalt road at a speed of 40kph and 80kph. Mode #2 intended to simulate lateral skidding by using a J-turn maneuver (90 degree rotation) on a dry asphalt road at a speed of 40kph and 80kph. Mode #3 intended to simulate lateral skidding by using a spin turn (180 degree rotation) on a dry asphalt road at a speed of 40kph and 80kph. GMLAN speeds and GPS speeds were collected to compare speed differences between the EDR speed and the actual vehicle speed. Extra testing was performed at other speed condition such as 20kph, 60kph, 100kph. But this paper only discussed 40kph and 80kph data only because these data show a clear speed trend.

Test Mode

Mode #1 Hard braking test was conduct at 40km/h and 80km/h (table 3).

Mode # 2 J-turn test was conduct at 40km/h and 80km/h (table 3).

Mode # 3 Spin turn test was conduct at 40km/h and 80km/h (table 3).

Table3. Test mode

Speed[km/h]	Hard braking	J-turn	Spin turn
40	X	X	X
80	X	X	X

Test conditions

Test site Test was conducted at Chung-na proving ground of GM Korea. Surface condition was dry asphalt.

Test Vehicle The AVEO (Picture 1) and CRUZE (Picture 2) were chosen for the vehicle maneuver tests. The Vehicle Identification Number (VIN) of AVEO is 'KLATA48EDCB000327'and CRUZE is 'KLAJA695DDK006345'. These vehicles use the GMLAN for the electric communication. The AVEO had no ABS and was equipped with KUMHO tires (P205/55/R16, 35psi). The CRUZE had ABS and was equipped with HANKOOK tires (P205/65/R16, 35psi).

Picture1. AVEO without ABS

Picture2. CRUZE with ABS

Instrument GMLAN bus data and GPS data from the GPS signal measurement system (picture 4) was recorded by a DEWE3010 data acquisition instrument. The GMLAN bus data was accessed through the DLC (Data Link Control) connector. The DEWE3010 instrument has a 32 bit data transfer rate at 33Mhz and 16 Analog input channels, with 16 bit resolution, and 200kS/s sampling rate (picture 3). Speed data from the GMLAN and GPS was recorded to every 10ms (0.01 sec) by the DEWE3010. GPS speed was measured by a RT4100 (picture 4) with external GPS antenna AT575-70 (picture 5) that has 0.1 km/h RMS speed precision, and 250Hz refresh rate.

Picture3. DEWE3010 – Data acquisition system

Picture4. RT4100 - GPS signal measurement system

Picture5. AT575-70 - External GPS antenna
(Installed on the roof center of vehicle.)

TEST RESULT

For discussion, the GPS speed represents actual vehicle speed. The GMLAN speed represents EDR speed. Vehicle speed differences between the GPS

speed and GMLAN speed during a straight run was about ±1km/h. GPS speed and GMLAN speed was recorded at a 10ms sample rate by the data acquisition system. GMLAN speed was recorded at a 100ms step due to BCM provides vehicle speed as 100ms periodic message rate. Unit of Vehicle speed for EDR is 1km/h. Therefore both the GMLAN and GPS speed data recorded from maneuver tests were truncated to the nearest tenth decimal point to match the EDR recording specification. Also GMLAN speed data was modified to compensate for the 200ms time lag caused by ECU and BCM communication the GMLAN. For these reason, time of GMLAN speed shifted 200ms ahead.

Result of mode #1 (Hard braking test)

For the AVEO with non-ABS, the GMLAN speed recorded as '0' while the GPS speed decreased continually (Figure 1, 2). In figure 1, the non-ABS vehicle will lock the wheels and the transmission output shaft stops. So the vehicle speed input to the GMLAN would be zero around 0.8 msec. In reality, the vehicle is still moving and stops about a second later. In ABS vehicles, the wheels tend not to lock up so you expect to see the data trend closer with the ASB activated.

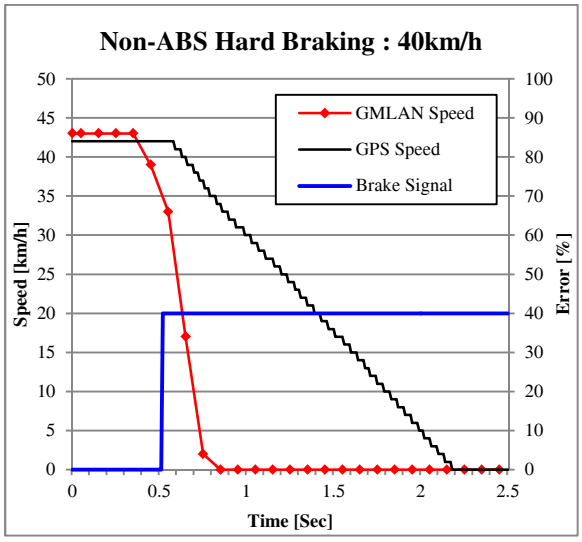

Figure1. Speed comparison of Non-ABS(AVEO) hard braking test at 40km/h

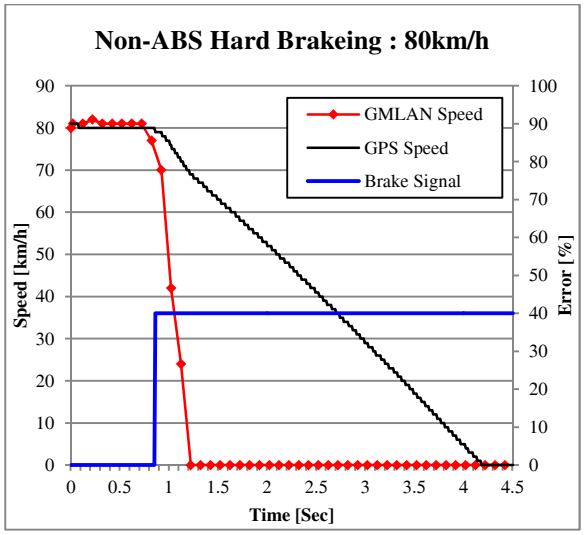

Figure2. Speed comparison of Non-ABS(AVEO) hard braking test at 80km/h

For the CRUZE with ABS, the GMLAN speed recorded lower than the GPS speed. The GMLAN speed of CRUZE with ABS showed fluctuation due to ABS operation during the maneuvers. This trend is more clearly indicated at 40km/h test (Figure 3). That trend decreased at 80km/h test but fluctuation was still indicated (Figure4).

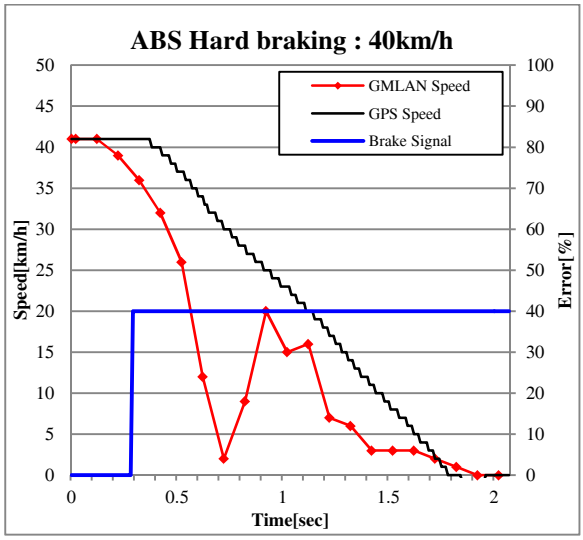

Figure3. Speed comparison of ABS(CRUZE) hard braking test at 40km/h

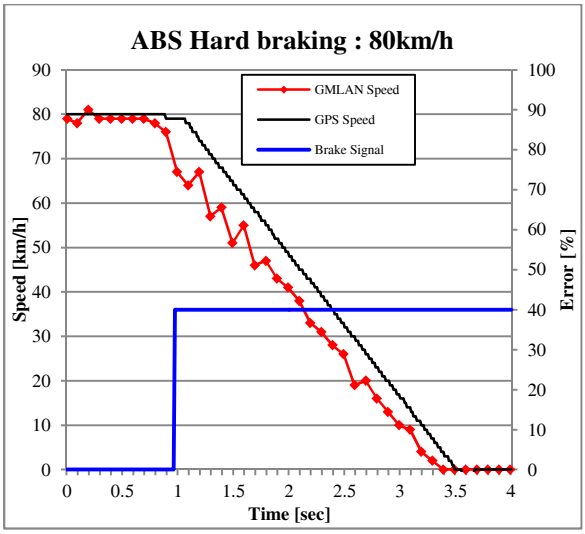

Figure4. Speed comparison of ABS(CRUZE) hard braking test at 80km/h

Result of mode #2(J-turn test)

The trend of speed differences between the GMLAN speed and GPS speed is similar from the result of test mode #1(Figure 5, 7, 8) except for fluctuation trend. GMLAN speed fluctuation was only indicated at the 80km/h test of Non-ABS AVEO due to brake pedal application during the maneuver. The Brake signal still recorded as 'ON' at fluctuation of the 80km/h test of Non-ABS AVEO, but the driver released the brake pedal slightly to maintain vehicle control in the maneuver. (Figure 6). The Brake signal is not matched to the decline start point in all of J-turn test results because test driver used the parking brake prior to brake pedal to make the J-turn.

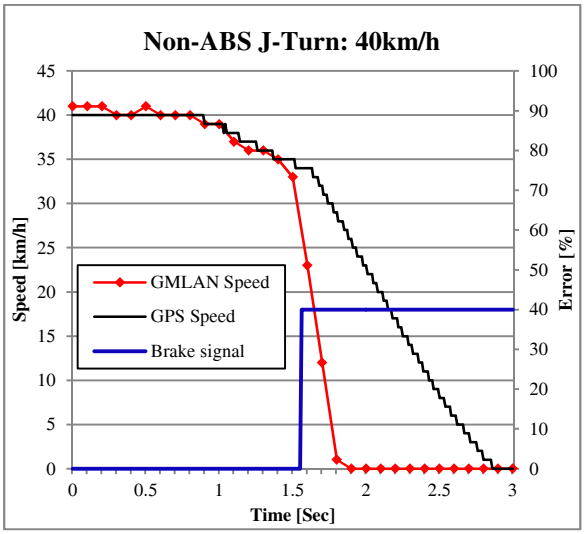

Figure5. Speed comparison of Non-ABS(AVEO) J-turn test at 40km/h

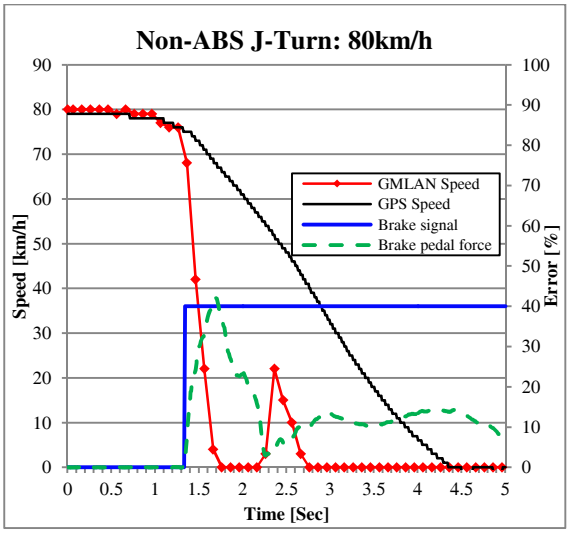

Figure6. Speed comparison of Non-ABS(AVEO) J-turn test at 80km/h

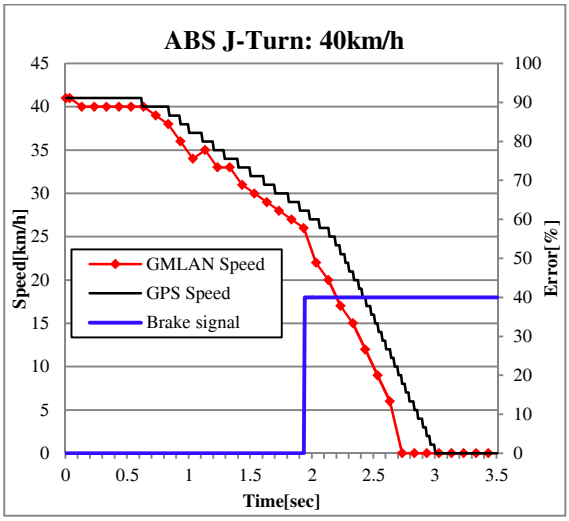

Figure7. Speed comparison of ABS(CRUZE) J-turn test at 40km/h

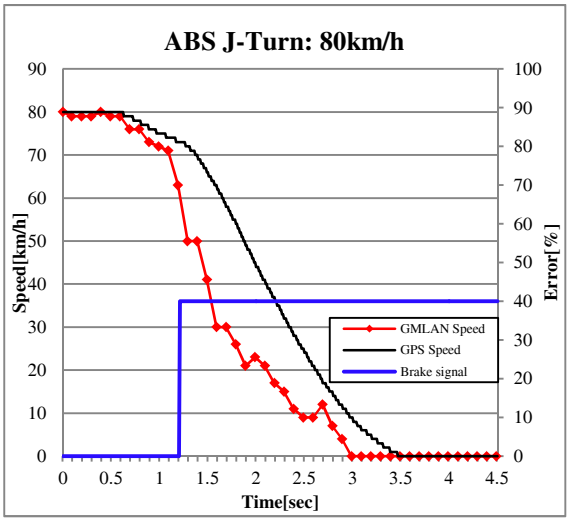

Figure8. Speed comparison of ABS(CRUZE) J-turn test at 80km/h

Result of mode #3 (Spin turn test)

For the AVEO with Non-ABS, the test result of mode #1 and mode #2 was shown as '0' GMLAN speed while the GPS speed decreased continually. The result of mode #3 does not show the same characteristic. Speed does not go to zero in mode #3 because the front wheels of vehicle still rotate during the turning maneuver due to the test driver using the parking brake prior to using the pedal brake to make the spin turn (Figure 9, 10, 11, 12). Fluctuation of the GMLAN Speed was not shown for the test result of the CRUZE with ABS because the test driver did not use brake pedal(Figure 11, 12). In the 80km/h test, the GPS speed of CRUZE with ABS and the AVEO with Non-ABS reached '0' then showed a negative movement due to vehicle moving backward at near 110 degree of rotation (Figure 10, 12). The Rotation trend of the 80km/h spin turn test for the AVEO and CRUZE can be found in Appendix A. in the 80km/h test of the AVEO with Non-ABS, the GMLAN speed recorded '0' while the GPS speed indicated a negative because the test driver used the brake pedal.(Figure 10). In the 80km/h test result of CRUZE with ABS, the GMLAN speed recorded as '0' then indicated a negative while GPS speed indicated a negative because test driver did not use the brake pedal(Figure 12).

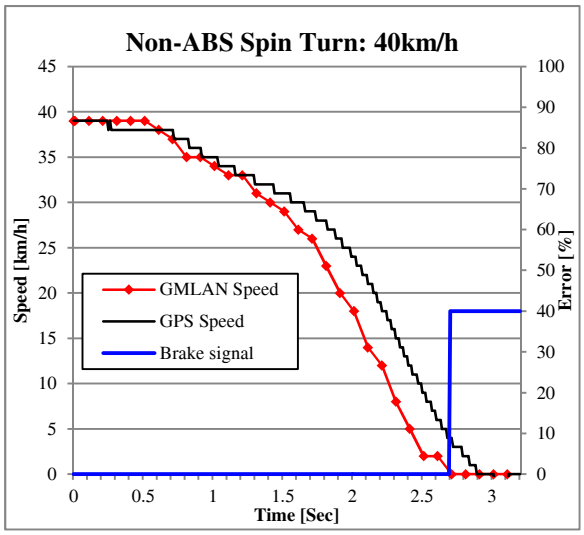

Figure9. Speed comparison of AVEO with Non-ABS Spin-turn test at 40km/h

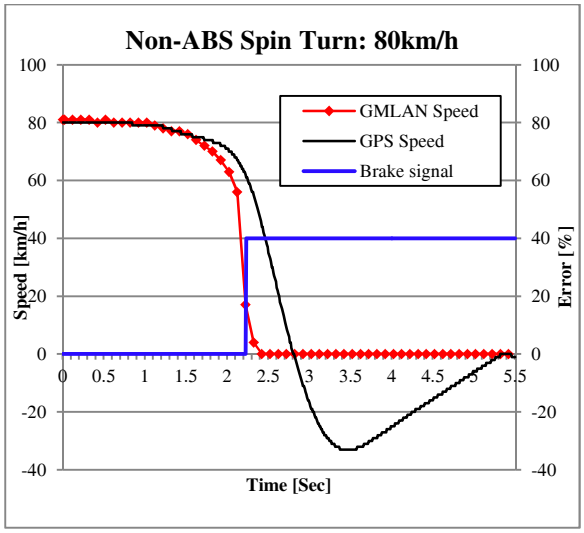

Figure10. Speed comparison of Non-ABS(AVEO) Spin-turn test at 80km/h

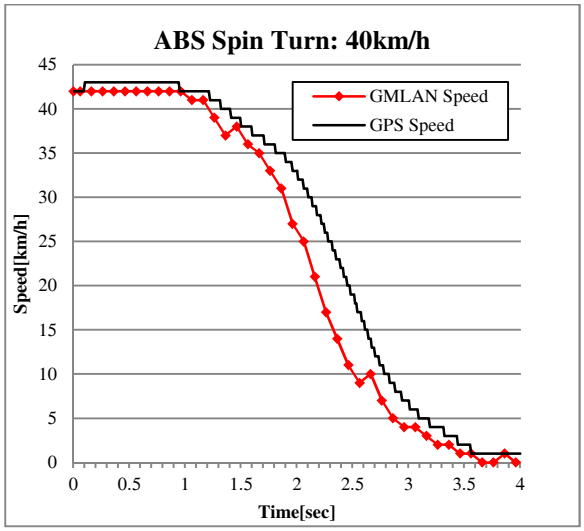

Figure11. Speed comparison of ABS(CRUZE) Spin-turn test at 40km/h

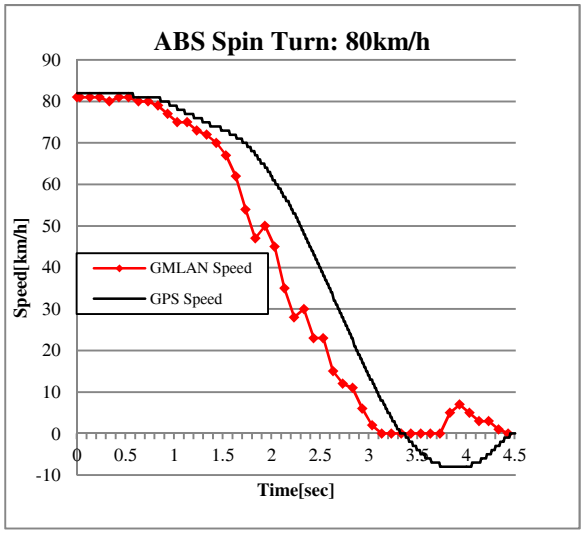

Figure12. Speed comparison of ABS(CRUZE) Spin-turn test at 80km/h

CONCLUSIONS

Hard braking test

- The GMLAN speed of the AVEO with Non-ABS was recorded as '0' while actual vehicle speed decreased continually. The non-ABS vehicle will lock the wheels and the transmission output shaft stops. The vehicle speed input to the GMLAN would be zero around 0.8 msec. In reality, the vehicle is still moving and stops about a second later. In ABS vehicles, the wheels tend not to lock up so you expect to see closer data trends when the ASB is activated.

- Fluctuation appeared on the GMLAN speed of the ABS vehicle. ABS releases brake pressure on a wheel when wheel lock-up is detected during braking and then repeats braking and releasing. For these reasons the GMLAN vehicle speed would show a fluctuation trend as evidenced in the test result of this paper.

- The Speed difference of a Non-ABS vehicle is higher than an ABS vehicle. Detail figures of speed differences are shown as below table4.

Table4. Speed differences of hard braking test

(*Speed difference = GPS speed - GMLAN speed, [km])

Non-ABS : AVEO ABS : CRUZE	Hard braking			
	40km/h test		80km/h test	
	Non-ABS	ABS	Non-ABS	ABS
0 sec (After maneuver)	9	5	9	12
0.5 sec	32	29	67	9
1 sec	22	5	59	8
1.5 sec	12	5	50	9
2 sec	2	2	41	10
2.5 sec	-	-	32	7
3 sec	-	-	22	4
3.5 sec	-	-	7	0

J-turn test

- The GMLAN speed of the AVEO with Non-ABS was recorded as '0' while the actual vehicle speed decreased continually due to the same reasons as discussed for hard brake test result.

- Fluctuations did not appear in GMLAN speed regardless of an ABS vehicle or non-ABS vehicle except in the 80km/h test of the AVEO with Non-ABS. GMLAN speed fluctuation was only indicated for the 80km/h test of Non-ABS AVEO due to brake pedal application during the maneuver.

- Speed difference of Non-ABS vehicle is higher than ABS vehicle. Detail figures of speed differences are shown as below table5.

Table5. Speed differences of J-turn test

(*Speed difference = GPS speed - GMLAN speed, [km]

Non-ABS : AVEO ABS : CRUZE	J-turn			
	40km/h test		80km/h test	
	Non-ABS	ABS	Non-ABS	ABS
0 sec (After maneuver)	0	2	0	1
0.5 sec	0	2	32	2
1 sec	19	2	65	11
1.5 sec	20	2	52	32
2 sec	9	6	41	22
2.5 sec	0	8	31	17
3 sec	0	1	19	7
3.5 sec	-	-	6	2

Spin turn test

- The GMLAN speed does not indicate as '0' while actual vehicle speed decreased continually regardless ABS vehicle and non-ABS vehicle.

- Fluctuations did not appear for GMLAN speed. Test driver use parking brake prior to use brake pedal for non-ABS vehicle and does not use brake pedal for ABS vehicle.

- GPS speed of ABS vehicle and non-ABS vehicle reached '0' then indicated negative movement in the 80km/h test. For the 80km/h test of AVEO with Non-ABS, the GMLAN speed recorded '0' while the GPS speed indicated a negative because the test driver used the brake pedal.(Figure 10). For the 80km/h test result of CRUZE with ABS, The GMLAN speed recorded as '0' then indicated a positive while the GPS speed indicated a negative because the test driver did not use the brake pedal.

- Detail figures of speed difference are shown as below table6.

Table6. Speed differences of spin turn test

(*Speed difference = GPS speed - GMLAN speed, [km])

Non-ABS : AVEO ABS : CRUZE	Spin turn			
	40km/h test		80km/h test	
	Non-ABS	ABS	Non-ABS	ABS
0 sec (After maneuver)	0	0	0	1

0.5 sec	1	3	5	4
1 sec	1	3	50	4
1.5 sec	5	8	9	21
2 sec	7	8	-25	25
2.5 sec	4	3	-33	18
3 sec	0	2	-27	10
3.5 sec	-	-	-16	-7
4 sec	-	-	-6	-11
4.5 sec	-	-	-1	0

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Appendix A. Rotation trend of 80km/h spin turn test of AVEO and CRUZE