CPSC Staff Statement on SEA, Ltd. Report "Vehicle Characteristics Measurements of All-Terrain Vehicles"[1]
January 2017

The report titled, "Vehicle Characteristics Measurements of All-Terrain Vehicles," presents the results of vehicle testing conducted by SEA Limited (SEA) on 12 model year 2014-2015 adult single-rider all-terrain vehicles (ATVs) under contract HHSP233201400030I. This contract is funded by CPSC and is administered under an interagency agreement with the Department of Health and Human Services. The work represented by this report is part of a larger effort by CPSC staff to develop test methods, collect static and dynamic data, and make recommendations for improvement regarding ATV performance characteristics related to vehicle stability and safety. Follow-on work is underway to measure characteristics for the same 12 vehicles in the following special circumstances to determine the effects on vehicle dynamics: two persons riding (misuse), rider active weight shift, and operation on a groomed dirt surface. Follow-on work will also include testing of three selected vehicles with characteristics modified. Additionally, staff has identified a need for future testing when resources are available to include autonomous rollover testing and rollover simulation testing with a goal to discover recommendations that may improve injury mitigation.

[1] This statement was prepared by the CPSC staff, and the attached report was produced by SEA for CPSC staff. The statement and report have not been reviewed or approved by, and do not necessarily represent the views of, the Commission.

Vehicle Characteristics Measurements Of All-Terrain Vehicles

Results from Tests on Twelve 2014-2015 Model Year Vehicles

for:
Consumer Product Safety Commission

November 2016

Vehicle Dynamics Division
7001 Buffalo Parkway
Columbus, Ohio 43229

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"These comments are those of SEA, Ltd. staff, and they have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission."

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1. OVERVIEW

This report contains results from measurements made by SEA, Ltd. (SEA) for the Consumer Product Safety Commission (CPSC) under U.S. Department of Health and Human Services contract HHSP233201400030I.

This report basically covers the following general objective of the multi-task contract:

- CPSC staff requires static and dynamic test data on a cross-section of All-Terrain Vehicle (ATV) types and sizes in various load conditions to make recommendations for improving the safety of these widely used vehicles. Data obtained by this contract will provide a means of directly comparing commonly used static measures of stability characteristics to dynamically measured stability characteristics for the same vehicle.

This report contains test results for measurements made on twelve 2014-2015 model year vehicles. The vehicles are designated Vehicle A through Vehicle L. Vehicles A-J are model year 2014 vehicles, and Vehicles K and L are model year 2015 vehicles. All of the vehicles were selected by CPSC. All of the vehicles have straddle seating and their intended use is for a single occupant, the driver. All of the vehicles have clear warning labels stating "Never Carry a Passenger" or "Never Carry Passengers." All of the vehicles have handlebar (tiller) steering, thumb activated throttles, and hand and foot activated brakes.

The measured curb weights (weights with full fluids and no drivers or cargo) of the vehicles ranged from 395.5 lb to 832.0 lb. The measured average maximum speeds of the vehicles ranged from 45.7 mph to 74.0 mph in a loading condition representing driver only loading.

Table 1 contains a list of assorted vehicle information and tire specifications for the 12 vehicles. The measured curb weights and maximum speeds are listed, as are the loading conditions tested for each vehicle. The loading conditions used for the dynamic tests included Driver Plus Instrumentation (DPI) and Gross Vehicle Weight (GVW), which included a driver, instrumentation, and cargo needed to bring the test weight up to the manufacturers' specified Gross Vehicle Weight rating. Three of the vehicles, Vehicles B, H and I, were tested only in the DPI loading condition; because for these vehicles the added weight of the test driver and instrumentation brought the total test weight up to near their GVW weight ratings.

Also listed in Table 1 is information on the transmission types (Automatic or Manual) and whether the vehicle has a Solid Rear Axle or Independent Rear Suspension. All of the vehicles with solid rear axles are two-wheel drive (2WD) only vehicles. All of the vehicles with independent rear suspensions are equipped with selectable four-wheel drive, and some of these vehicles are also equipped with an option to select locked rear differential. Table 1 contains the manufacturers' specified driveline setting options for each of the vehicles. All of the vehicles were tested in two-wheel drive. The vehicles with solid rear axles naturally have locked rear differentials, and all of the vehicles with independent rear suspensions have open rear differentials when they are driven in two-wheel drive. All vehicles were tested in two-wheel drive mode, and in their most open driveline configurations.

Table 1 also lists the front and rear tire make, tire size, and tire pressure for each vehicle.

The vehicles were evaluated using both laboratory measurements and dynamic tests. The laboratory measurements were made by SEA in Columbus, Ohio using their Vehicle Inertia Measurement Facility (VIMF), their Tilt Table, and other laboratory equipment. The dynamic tests were performed by SEA on numerous dates between September 1, 2015 and November 3, 2015. Six of the vehicles were tested at the North Carolina Center for Automotive Research (NCCAR) in Garysburg, North Carolina and six of the vehicles were tested at the Transportation Research Center, Inc. (TRC) in East Liberty, Ohio. The dynamic test evaluations included steering maneuvers on NCCAR's and TRC's flat dry asphalt vehicle dynamics test pads.

This report contains four main sections: Overview, Laboratory Testing, Dynamic Testing, and Discussion of Test Results. There are also four appendices containing test results, and one appendix containing photographs of test equipment.

Table 1: Test Vehicle Information and Tire Specifications		
Vehicle A **Curb Weight: 523.9 lb** **Maximum Speed: 47.0 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Maxxis MU13	Maxxis MU13
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	3.6	3.6
Vehicle B **Curb Weight: 432.8 lb** **Maximum Speed: 70.0 mph** **Test Conditions: DPI**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Maxxis M976Y	Maxxis M976Y
Tire Size	AT21X7-10	AT20X10-9
Tire Pressure (psi)	4	4
Vehicle C **Curb Weight: 650.8 lb** **Maximum Speed: 66.0 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Maxxis MU19A	Maxxis MU19A
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	5	4.4
Vehicle D **Curb Weight: 714.0 lb** **Maximum Speed: 45.8 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Kaden Duro 45J	Kaden Duro 52J
Tire Size	AT25X8-12 6 Ply	AT25X10-12 6 Ply
Tire Pressure (psi)	5	5
Vehicle E **Curb Weight: 734.1 lb** **Maximum Speed: 45.7 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Kaden Duro 45J	Kaden Duro 52J
Tire Size	AT25X8-12 6 Ply	AT25X10-12 6 Ply
Tire Pressure (psi)	5	5
Vehicle F **Curb Weight: 526.2 lb** **Maximum Speed: 53.5 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Kenda Pathfinder	Kenda Pathfinder
Tire Size	AT22X7-10 4 Ply	AT22X10-10 4 Ply
Tire Pressure (psi)	4	3.5

Table 1 (Continued): Test Vehicle Information and Tire Specifications		
Vehicle G **Curb Weight: 694.0 lb** **Maximum Speed: 69.0 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD or 4WD**	
	Front Tires	Rear Tires
Tire Make	Duro DI-K911	Duro DI-K911
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	5	5
Vehicle H **Curb Weight: 395.5 lb** **Maximum Speed: 71.5 mph** **Test Conditions: DPI**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Dunlop KT391	Dunlop KT396
Tire Size	AT21X7R10 ☆☆	AT20X10R9 ☆☆
Tire Pressure (psi)	4.4	3.9
Vehicle I **Curb Weight: 408.4 lb** **Maximum Speed: 63.0 mph** **Test Conditions: DPI**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Ohtsu Radial HTRAK M/R101	Ohtsu Radial HTRAK M/R101
Tire Size	AT22X7-10 4 Ply	AT22X10-9 4 Ply
Tire Pressure (psi)	4	4
Vehicle J **Curb Weight: 649.8 lb** **Maximum Speed: 60.5 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2WD or AWD**	
	Front Tires	Rear Tires
Tire Make	Dunlop KT511	Dunlop KT515
Tire Size	AT25X8 R12	AT25X10 R12
Tire Pressure (psi)	4.4	3.6
Vehicle K **Curb Weight: 832.0 lb** **Maximum Speed: 74.0 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2x4, 4x4, or 4x4 Lock**	
	Front Tires	Rear Tires
Tire Make	Carlisle AT489 II	Carlisle AT489 II
Tire Size	AT 26X8-14 6 Ply	AT 26X10-14 6 Ply
Tire Pressure (psi)	7	7
Vehicle L **Curb Weight: 716.4 lb** **Maximum Speed: 52.7 mph** **Test Conditions: DPI and GVW**	**Automatic Transmission** **Independent Rear Suspension** **2x4 or AWD**	
	Front Tires	Rear Tires
Tire Make	Wanda NS388	Wanda NS388
Tire Size	AT24X8-12 6 Ply	AT24X10-12 6 Ply
Tire Pressure (psi)	5	5

2. LABORATORY TESTING

This section describes the laboratory measurements made as well as computations of various rollover resistance metrics and other vehicle characteristics. This section is divided into four parts: one covering the vehicle loading conditions used for the tests, one covering the Vehicle Inertia Measurement Facility (VIMF) tests, one covering the Tilt Table tests, and one covering the steering ratio tests. Tabular results from all of the measurements and metrics discussed in this section are contained in Appendix A.

2.1 Vehicle Loading Conditions

The three loading conditions described below were used for the tests.

1. **Driver**
   This loading condition was specified to be the vehicle curb condition plus a 213 lb driver. For this loading condition a Hybrid II test dummy weighing 164 lb was used and ballast was added to its lap to bring the driver weight up to nominally 213 lb. The test dummy was seated on each vehicle with its feet on the footrests and its hands attached to the handlebars. The vehicle weight for this loading is nominally 213 lb more than the vehicle curb weight.

2. **Driver Plus Instrumentation (DPI)**
   This loading condition was specified to be the vehicle curb condition plus the weight of the actual test driver, test instrumentation (including measurement transducers, SEA's All-Terrain Vehicle Automated Steering Controller (ATV ASC),[1] an auxiliary 24V battery, and ATV safety outriggers.[2] Table 2 lists the nominal weights of the components that comprise the DPI loading condition. The vehicle weight for the DPI loading condition is nominally 235 lb more than the vehicle curb weight. For the laboratory tests conducted in the DPI loading condition, a Hybrid II test dummy, ballasted to nominally 172 lb, was used as the driver weight.

   This is one of the loading conditions that was used during the dynamic testing phase of this project, and it was designed to represent the Driver loading condition. However, the need to add test instrumentation, a steering controller, and safety outriggers, and the fact that both of the SEA test drivers weigh nominally 172 lb, caused the nominal DPI loading of 235 lb to exceed the Driver loading of 213 lb. Also, for several of the ATVs that did

[1] As part of this project, SEA designed the ATV ASC. The ATV ASC consists of a computer-controlled 24V electric motor that mounts to the front rack of an ATV. A four bar linkage arrangement is used to connect the motor drive gear to an aluminum rod that is connected to the ATV steering column beneath the ATV handlebars. This arrangement allows the driver to keep their hands in their usual positions on the handlebars when the ATV ASC inputs steering commands to the steering column. The ATV ASC also includes a National Instruments (NI) cRIO (the on-vehicle computer with the steering controller and data acquisition software), an antenna for wireless communication, and a small driver display screen. Page 1 of Appendix E contains photographs of the ATV ASC.

[2] SEA designed ATV-specific safety outriggers consisting of a single aluminum tubular beam structure that mounts to the underside of the ATVs. Adjustable height nylon pads are mounted to the ends of the outrigger beam, and these interact with the test surface to prevent the vehicles from tipping over. Page 2 of Appendix E contains photographs of the ATV safety outriggers.

not have front racks able to support the ASC ATV motor base, additional support members made of 80/20 T-slot aluminum bars were added to support the ASC ATV motor base. For these vehicles, the DPI loading was somewhat more than 235 lb. Appendix A contains a listing of the actual DPI weights used for each vehicle.

3. **Gross Vehicle Weight (GVW)**
   This loading condition is the manufacturers' specified GVW, which was determined by adding the specified maximum driver weight and the specified maximum cargo weights allowed on the front and rear racks. GVW loading was achieved by adding front and rear rack ballast to each vehicle as loaded in their DPI condition.

   Table 3 is a summary of the GVW loading used for each vehicle. Table 3 lists the manufacturers' specified total added weight needed to achieve GVW, and the maximum front, rear, and total rack weights. The total rack weight needed to achieve GVW is the total added weight needed to achieve GVW minus the DPI loading, which is nominally 235 lb. For two of the vehicles, Vehicles F and J, the maximum front and rear rack weights were exceeded to achieve the manufacturers' specified GVW loading. The front rack weights were comprised of 5, 10, 25 and 50 lb. rectangular steel bars, and the rear rack weights were comprised of a wooden ballast box containing lead shot bags and, in some cases, the rectangular steel bars were also used as part of the rear rack weight. Page 3 of Appendix E contains photographs of the front and rear rack ballast used on one of the test vehicles.

   The front and rear rack weights needed to achieve total rack weight were proportioned to closely match the proportion of the manufacturers' maximum front and rear rack weight specifications. The actual GVW weights used for each vehicle are contained in Appendix A, and in all cases they are close to the manufacturers' specified GVW.

The VIMF and Tilt Table tests were conducted in all three loading conditions, with three exceptions. Vehicles B, H and I are small ATVs with manufacturer-specified maximum loading of 220 lb, 250 lb and 243 lb, respectively. For these three vehicles, since their GVW loading condition was so close to the DPI loading condition, no VIMF, Tilt Table, or dynamic tests were conducted on these three vehicles in the GVW loading condition.

Table 2: Driver Plus Instrumentation (DPI) Loading	
Component	**Weight (lb)**
ATV ASC: Base Plate, Motor, National Instruments (NI) cRIO, Electronics and Enclosures	29.0
RT3002 GPS/IMU and Steering Column Encoder	6.7
Auxiliary 24V Battery	2.7
ATV Outriggers	24.5
Test Driver, Helmet and Safety Gear	172.1
Total Nominal DPI Weight	**235.0**

Table 3: Gross Vehicle Weight (GVW) Loading									
Vehicle	Manufacturer Specifications				Total Rack Weight Needed To Reach GVW (lb)	Amount Rack Weight Exceeded (lb)	Front Ballast Used (lb)	Rear Ballast Used (lb)	Total Ballast Used (lb)
	Total Added Weight for GVW (lb)	Front Rack Weight (lb)	Rear Rack Weight (lb)	Total Rack Weight (lb)					
A	463	88	176	264	228	0	75	155	230
B	220	NA	NA	NA	NA	NA	NA	NA	NA
C	485	99	187	286	250	0	85	165	250
D	515	100	200	300	280	0	95	185	280
E	515	100	200	300	280	0	95	185	280
F	400	50	100	150	165	15	55	110	165
G	474	88	176	264	239	0	80	160	240
H	250	NA	NA	NA	NA	NA	NA	NA	NA
I	243	NA	NA	NA	NA	NA	NA	NA	NA
J	485	66	133	199	250	51	85	165	250
K	575	120	240	360	340	0	115	225	340
L	485	90	180	270	250	0	85	165	250

2.2 Vehicle Inertia Measurement Facility (VIMF) Tests

Laboratory measurements of vehicle weight (including the four corner weights); vehicle center-of-gravity (CG) position (longitudinal, lateral, and vertical (CG height)); vehicle pitch, roll, and yaw moments of inertia; and roll/yaw product of inertia were made by SEA using their Vehicle Inertia Measurement Facility (VIMF).[3] Measurements of front track width, rear track width, and wheelbase were also made. SEA conducts measurements of vehicle CG height, average track width, and Static Stability Factor (SSF) for the National Highway Traffic Safety Administration (NHTSA) New Car Assessment Program (NCAP). Where applicable, the same protocols and equipment used for the NCAP testing were used during this CPSC testing.

The vehicle CG longitudinal position is expressed as a distance from the front axle. The vehicle CG lateral position is expressed as a lateral distance from the vehicle centerline; CG positions to the right (passenger's side) of the centerline are positive. The vehicle CG height is expressed as the distance of the vehicle center of gravity above the road plane. The CG height test results are determined from five separate VIMF sub-tests. The first test finds the nominal zero angle of the platform/vehicle system, and the remaining four are the actual CG height tests. Two tests are performed with the vehicle tilted forward, and two are performed with the vehicle tilted rearward. Results from the four tests are then averaged together.

The moments and product of inertia for a vehicle are computed relative to the vehicle's center of gravity, using an orthogonal coordinate system with its origin at the vehicle center of gravity. The X-axis of the coordinate system is directed forward and parallel to the road plane, the Y-axis is directed to the driver's right and is also parallel to the road plane, and the Z-axis is directed downward. By definition, all moments of inertia are positive, but the roll/yaw product of inertia can take on positive and negative values. The moment of inertia tests are repeated three times each and the results averaged.

In addition to the direct measurements provided by the VIMF, two other metrics that are used to characterize vehicle rollover resistance were computed, namely, the Static Stability Factor (SSF) and the lateral stability coefficient (K_{ST}).

SSF is a fundamental rollover resistance metric which equals the lateral acceleration in units of g at which rollover begins in the most simplified rollover analysis of a vehicle represented by a rigid body without suspension movement or tire deflections. NHTSA uses SSF, measured with vehicles loaded in a Driver Only configuration, to evaluate passenger vehicle rollover resistance for NCAP. SSF is given by:

$$SSF = \frac{T_{AVE}}{2 \times H_{CG}}$$

where: T_{AVE} is the Average Track Width, and
H_{CG} is the Vehicle CG Height.

[3] *The Design of a Vehicle Inertia Measurement Facility*, Heydinger, G.J., Durisek, N.J., Coovert, D.A., Guenther, D.A., and Novak, S.J., SAE Paper No. 950309, February, 1995.

K_{ST} is similar to SSF in that it represents the acceleration in g's at which rollover begins in the most simplified rollover analysis of a vehicle with different front and rear track widths represented by a rigid body without suspension movement or tire deflections. For vehicles with equal front and rear track widths, K_{ST} and SSF are equal. K_{ST} is given by:

$$KST = \frac{L \times T_R + L_{CG} \times (T_F - T_R)}{2 \times L \times H_{CG}}$$

where: L is the Vehicle Wheelbase,
T_F is the Front Track Width,
T_R is the Rear Track Width, and
L_{CG} is the Longitudinal Distance from the Rear Axle to the CG, and
H_{CG} is the Vehicle CG Height.

Appendix A contains results from all of the VIMF tests, and it also contains the weight, track width, wheelbase, and CG longitudinal and lateral positions for each vehicle in their Curb condition.

2.3 Tilt Table Tests

SEA built a tilt table consisting of a rigid steel platform mounted on top of a yaw bearing, shown in the photographs on Page 4 of Appendix E. The yaw bearing allows the platform to be rotated (in 90 degree increments) so that lateral tilts (left-side leading and right-side leading), forward tilts (front-end leading), and rearward tilts (rear-end leading) can be conducted without removing and reloading the vehicle. A hydraulic cylinder was used to tilt the yaw bearing and platform assembly, up to 60 degrees from horizontal.

Tilt Table tests were performed in the Driver and DPI loading conditions for all vehicles, and in the GVW loading condition for all vehicles, except Vehicles B, H and I. The tilts were performed in four directions: left-side leading, right-side leading, front-end leading, and rear-end leading.

For the lateral tilts, the vehicles were tilted in a direction nominally parallel to their longitudinal or roll axis. The outsides of the low side tires were aligned to be parallel to the tilt axis prior to testing. The platform was gradually tilted to the point when both of the high side tires lifted off of the platform. The vehicles were prevented from tilting completely off of the platform by straps that restrained further tilting once the high side tires lifted about two to three inches off of the platform. A high friction surface, a thin aluminum plate with its top surface covered with marine grade safety walk paint, was secured to the platform in the areas beneath all four tires. This surface prevented the vehicles from sliding sideways during the lateral tilt table tests.

For the longitudinal tilts (the forward and rearward tilts), the vehicles were tilted in a direction nominally parallel to their pitch axis. To prevent the vehicles for rolling during these tests, the vehicle transmissions were locked (they were put in park or in gear), their hand brakes were applied using a hose clamp, and if necessary, straps were wrapped around the front and/or rear tires and secured to the vehicle chassis. The forward and rearward tilt angles needed to get two-wheel lift are greater than the tilt angles needed to get lateral tilt two-wheel lift; and the high friction surface was not adequate to prevent the vehicles from sliding on the platform. Preliminary testing was conducted using a 1-inch high trip rail, but some vehicles “jumped” the 1-inch high trip rail and slid on the platform. Therefore, a 2-inch high trip rail (a 2x2 inch square aluminum tube) was used for all longitudinal tilt table tests. The tires were rolled up against the 2-inch high trip rail prior to locking the transmissions, setting the brakes, and applying the roll-preventing tire straps.

For the longitudinal tilts, the low side tires were aligned to be parallel to the tilt axis. The platform was gradually tilted to the point when both of the high side tires lifted off of the platform. The vehicles were prevented from pitching completely off of the platform by straps that restrained further tilting once the high side tires lifted about two to three inches off of the platform. A high friction surface, a thin aluminum plate with its top surface covered with marine grade safety walk paint, was secured to the platform in the areas beneath all four tires; and the 2-inch high trip rail was used for all longitudinal tilt table tests.

The important factors involved in accurate tilt table testing include having a rigid and flat platform; having the ability to produce slow, smooth and consistent tilt rates; and having accurate and repeatable measures of tilt angle and point of wheel lift. The SEA tilt table platform is very rigid, and it was designed to have deflections of less than 0.1 inch for all ATV vehicles tested. It is also very flat, with a flatness tolerance of $\pm$ 0.1 inch. The hydraulic cylinder used to tilt the platform is controlled to provide for smooth tilting at rates as slow as 0.1 deg/sec.

A high-accuracy, two-axis (one aligned with the right/left tilt axis and one aligned with the fore/aft tilt axis) angle sensor is mounted to the platform to record the tilt angles throughout the tilt table tests. The point of two-wheel lift is determined visually, and the observer generates a signal that is recorded by the data acquisition system by pushing a button on a hand held trigger. Typically five or six tilts to two-wheel lift were conducted for each vehicle configuration tested. The tests with the closest three angles of two-wheel lift were selected and averaged together to determine the final angle of two-wheel lift. Based on repeatability evaluations conducted using a range of ATVs, SEA believes that the repeatability of the measurements of two-wheel lift is within +/- 0.1 degrees.

For left side leading and right side leading tilts, the angle at which two-wheel lift occurs is referred to as the Tilt Table Angle (TTA). In addition to measuring TTA, the tilt table test results provide a measure of the rollover resistance metric Tilt Table Ratio (TTR). TTR is the tangent of the TTA. TTR values are lower than SSF values because suspension and tire deflections during the tilt table tests reduce the effective track widths below the values based on the rigid body concept that is the basis for SSF. During tilt table tests the load perpendicular to the road plane decreases causing the CG to rise, which also contributes to TTR being less than SSF. TTR is computed mathematically using:

$$\mathrm{TTR} = tan\left(\mathrm{TTA}\right)$$

For front end leading tilts, the angle at which two-wheel lift occurs is referred to here as Forward Tilt Table Angle (FTTA); and for rear end leading tilts, the angle at which two-wheel lift occurs is referred to here as Rearward Tilt Table Angle (RTTA). In addition to measuring FTTA and

RTTA, the tilt table test results provide measures of a vehicle's pitch-over resistance, metrics referred to here as Froward Tilt Table Ratio (FTTR) and Rearward Tilt Table Angle (RTTR). FTTR and RTTR are computed using:

$$\text{FTTR} = \mathit{tan}\left(\text{FTTA}\right)$$

$$\text{RTTR} = \mathit{tan}\left(\text{RTTA}\right)$$

2.4 Steering Ratio Tests

Steering ratio tests were conducted with the vehicles in their DPI loading condition. The steering ratio tests consisted of placing the front tires on commercial low friction wheel alignment pads and placing the rear tires on blocks of the same thickness as the alignment pads. The steering column angle (the handlebar angle) was measured using the on-vehicle steering column sensor, and the right and left roadwheel angles are measured using the angle gages on the alignment pads. To conduct the tests, the steering handlebar was moved incrementally from zero degrees, to its full lock position to the right, to its full lock position to the left, and returned back to zero degrees. The handlebar angle increments used were 0°, ±5°, ±10°, ±15°, ±20°, ±30°, for some vehicles ±40°, and full lock in both directions. Both the right side and left side roadwheel angles were recorded at all steering positions. Linear curve fits of the measured data in the range of ±10° of steering column (handlebar) angle were used to compute the overall steering ratios. The overall steering ratios are listed in Appendix A, and graphical results from these tests are contained in Appendix C.

3. DYNAMIC TESTING

This section describes the dynamic tests conducted on numerous dates between September 1, 2015 and November 3, 2015. Six of the vehicles were tested at the North Carolina Center for Automotive Research (NCCAR) in Garysburg, North Carolina and six of the vehicles were tested at the Transportation Research Center, Inc. (TRC) in East Liberty, Ohio. The dynamic test evaluations included steering maneuvers on NCCAR's and TRC's flat dry asphalt vehicle dynamics test pads. All vehicles were tested in two-wheel drive mode, and in their most-open driveline configurations.

For all of the vehicles, SEA used their ATV ASC, ATV aluminum safety outriggers, and the instrumentation listed in Table 4.

The RT3002 was mounted on the ATV ASC base frame, which was mounted to the front rack of each vehicle. For each vehicle, the longitudinal, lateral, and vertical offsets from the center of the RT3002 to the actual vehicle CG location were measured and entered into the RT3002 system software. This information was used to translate the measured quantities to those at the CG of the loaded vehicle. The lateral accelerations measured and reported herein are accelerations parallel to the road plane, as opposed to vehicle body-fixed accelerations.

Steering column angle (handlebar steering angle) was measured using a rotary encoder. Page 5 of Appendix E contains photographs of the arrangement used to measure steering column angle on one of the test vehicles. A split sheave, with an inner (bore) diameter sized to fit securely around the steering column shaft and a known outer (pitch) diameter, was fixed around each steering column. Another sheave with known pitch diameter was attached to the rotary encoder. The base of the encoder was mounted onto a 1-inch diameter aluminum rod that was mounted to the frame members of the vehicle that contained the mounting for the steering column bearings. The two sheaves were nominally mounted in a plane that is perpendicular to the steering column shaft. One end of a thin metal cable was attached to the sheave on the steering column. The cable was then wrapped several times around the sheave on the encoder. A steel spring that provides several inches of travel was used to hold the cable in tension at a location between where the cable leaves the sheave on the encoder and where its other end was ultimately attached to the frame of the vehicle. This two-sheave arrangement provided for reliable measurement of the steering column angle (handlebar steering angle).

In total, over 1,500 dynamic tests were performed on the 12 vehicles. The following suite of dynamic tests was performed in the DPI loading condition for each vehicle:

- **Constant Radius (50 ft) (Circle) Tests**
- **Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)**
- **Constant Speed (20 mph) Slowly Increasing Steer Tests**
- **Constant Steer Tests (Yaw Rate Ratio Tests)**
- **Steering Flick Tests (20 mph)**
- **Sinusoidal Sweep Steering (Frequency Response) Tests (15 mph)**

For the nine vehicles tested in the GVW loading condition, the following set of dynamic tests were conducted:

- **Constant Radius (50 ft) (Circle) Tests**
- **Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)**
- **Steering Flick Tests (20 mph)**
- **Sinusoidal Sweep Steering (Frequency Response) Tests (20 mph)**

Table 4: Instrumentation Used During Dynamic Testing

Transducer	Measurement	Range	Accuracy
Oxford Technical Solutions RT3002 Inertial and GPS Navigation System	Longitudinal, Lateral, and Vertical Accelerations	± 100 m/s^2 (± 10 g)	0.01 m/s^2 (0.001 g)
	Roll, Pitch, and Yaw Rates	± 100 deg/s	0.01 deg/s
	Speed	No Limit Specified	0.05 km/h (0.03 mph)
	Roll and Pitch Angles	-180 to +180 deg	0.03 deg
	Vehicle Heading	0 to 360 deg	0.1 deg
Steering Column Encoder	Steering Column Angle (Handlebar Angle)	No Limit Specified	± 0.25 deg

The ATVs were equipped with a small driver-alert light that was visible to the driver. The light was turned on whenever the lateral acceleration level reached a pre-determined level. For the Constant Radius Circle tests, the Constant Speed Slowly Increasing Steer tests, and the Constant Steer tests, the driver-alert light was set to turn on whenever the lateral acceleration level was slightly above 0.4 g. For these tests, the processing of the ATV data collected focuses on lateral acceleration levels up to 0.4 g. Previous studies conducted by CPSC on Recreational Off-Highway Vehicles (ROVs) focused on lateral acceleration levels up to 0.5 g. ATVs generally have lower tip-up resistance than ROVs, and some ATVs tip up at lateral acceleration levels below 0.4 g. In order to reduce tire wear caused by conducting tests at high lateral acceleration levels and to mitigate severe tip-ups onto the safety outriggers, the driver-alert light was used for much of the ATV Constant Radius Circle tests, the Constant Speed Slowly Increasing Steer tests, and the Constant Steer tests. The test driver's used their own discretion regarding continuing these tests to higher lateral acceleration levels.

3.1 Constant Radius (50 ft) (Circle) Tests

Constant Radius or Circle tests were used to evaluate the vehicles' understeer characteristics.[4] A Constant Radius test involves driving a vehicle on a circular path of constant radius (50 ft in this case). The ATV ASC steering motor linkages to the handlebars were disconnected for these tests, and the test vehicles were manually driven in the clockwise and counterclockwise directions, with drivers making steering adjustments to maintain position on the circle. The slowly increasing speed method as opposed to a discrete speed method was used for these tests. It is more efficient to conduct slowly increasing speed circle tests than discrete speed circle tests, and the data reduction process is more straightforward.

For the Constant Radius tests, most vehicles were driven from a very low speed up to a speed where the lateral acceleration was above 0.4 g. However, some of the vehicles tipped up below lateral acceleration levels of 0.4 g in the Constant Radius tests.

The Constant Radius tests were used to determine steering angle gradients. The steering angle gradients are the slopes of the characteristic curves of roadwheel steer angle versus lateral acceleration. The circle tests were also used to determine if the vehicles transitioned from understeer to oversteer during the tests. Finally, roll gradients, vehicle roll angle response as a function of lateral acceleration, were computed from these tests.

Detailed results from the Constant Radius tests are contained in Appendix C for the DPI loading tests and in Appendix D for the GVW loading tests.

3.2 Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)

J-Turn tests, often referred to as step steer tests, involve imparting a rapid steering input up to a fixed magnitude while the vehicle is traveling along a straight path. For the dropped throttle J-Turn tests, the test driver drove each vehicle along a straight-line path at a speed slightly above 20 mph. He then dropped the throttle and triggered the ATV ASC to initiate the steering input precisely when the vehicle speed reached 20 mph. The handlebar steering input rates used were 30 deg/sec, and the steering dwell or hold time used was 4.0 seconds, at which time the steering angle was returned to 0 deg.

The J-Turn test procedure involved initially running tests with steering magnitudes less than the steering required to produce tip-up events, events that have visual two-wheel lift outcomes. The handlebar steering input magnitude was gradually increased in 1.0 degree increments to the point were a test run resulted in a two-wheel event. Then another test run using 0.5 degrees less steering input was used to refine the steering required for two-wheel lift. Once the steering input magnitude required for visual two-wheel lift was determined, repeat test runs using this steering input were conducted. Enough tests using this steering magnitude were conducted until five visual two-wheels lifts were achieved in each direction for the DPI loading condition tests, and three visual two-wheels lifts were achieved in each direction for the GVW loading condition tests.

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[4] SAE Surface Vehicle Recommended Practice - Steady-State Directional Control Test Procedures For Passenger Cars and Light Trucks, SAE J266, 1996.

These tests provided a measure of the minimum peak lateral acceleration (Threshold Ay) required to cause visual two-wheel lifts during the tests.

Detailed results from the Dropped Throttle J-Turn tests are contained in Appendix C for the DPI loading tests and in Appendix D for the GVW loading tests.

3.3 Constant Speed (20 mph) Slowly Increasing Steer Tests

Constant Speed Slowly Increasing Steer (SIS) tests were also used to evaluate the vehicles' understeer characteristics.[5] During these SIS tests, the test drivers tried to maintain a constant speed of 20 mph and the ATV ASC was programmed to apply slow handlebar steering input at the rate of 2.0 deg/sec. As mentioned previously, the driver-alert light was set to light up at lateral acceleration levels just above 0.4 g, and the SIS tests were terminated when this level of lateral acceleration was achieved, or the vehicle tipped up onto the safety outriggers.

Using methods appropriate for SIS tests, these tests were also used to determine if the vehicles transitioned from understeer to oversteer during the tests.

Detailed results from the SIS tests are contained in Appendix C for the DPI loading tests and in Appendix D for the GVW loading tests.

3.4 Constant Steer Tests (Yaw Rate Ratio Tests)

Constant Steer tests are yet another well established method used to evaluate a vehicle's understeer characteristics.[6] The ROV industry groups ROHVA and OPEI, as well as CPSC, have used Constant Steer tests to evaluate vehicle yaw rate divergence. The industry groups have developed protocols for computing the ratio of yaw rate gain at a high lateral acceleration range (0.4-0.5 g) divided by the yaw rate gain at a low lateral acceleration range (0.1-0.2 g), and this ratio is referred to here as Yaw Rate Ratio. At the time of this report, both ROVHA[7] and OPEI[8] have industry voluntary standards that describe similar test and data reduction protocols for computing Yaw Rate Ratio for ROVs. The same test and data reduction protocols were used for the current ATV testing. The only significant difference is that for the ATV testing, the high range of lateral accelerations was reduced to a range below 0.4 g.

The test procedure used for the Yaw Rate Ratio tests was:

1. Follow a 100 ft diameter (50 ft. radius) circle at a speed less than 10 mph until the mean steer angle required to maintain the circular path is established (this is referred to as

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[5] Ibid

[6] Ibid

[7] American National Standard for Recreational Off-Highway Vehicles, ANSI/ROHVA 1-2016, May 2016.

[8] American National Standard for Multipurpose Off-Highway Utility Vehicles, ANSI/OPEI B71.9-2016, August 2016.

"initial steer" in this report). Once the initial steer angle has been determined, bring the vehicle to a stop.

2. The ATV ASC was then used to steer the steering column (handlebars) to the initial steer angle and hold it there for the duration of the test.
3. The vehicle was then steadily accelerated at a rate not to exceed 1 mph/second. The test drivers intended to complete each test run in 60 seconds, and the tests for many of the vehicles are close to 60 seconds in duration. For some vehicles, the test times were shorter and for some vehicles they were longer, but all tests were between 30 and 120 seconds in duration.
4. The tests were ended when a lateral acceleration of at least 0.4 g was achieved, or when the vehicle tipped up onto the safety outriggers.
5. Items 2-4 were repeated until at least five runs in the first steer direction were completed.
6. Item 1 was repeated in the opposite steer direction, and then Items 2-4 were repeated until at least five runs in the opposite steer direction were completed.

If a vehicle understeers during portions of a Yaw Rate Ratio test, its path radius could increase significantly, based on the amount of its understeer. If the path of a vehicle became large enough to run off of the available test surface, the test starting on a 100 ft diameter was terminated and the testing was conducted using a starting diameter of 50 ft. There is also a provision in ANSI/ROHVA 1-2016 for using the smaller starting diameter if necessary.

3.5 Steering Flick Tests (20 mph)

The ATV ASC was disconnected for the Steering Flick tests. The Steering Flick tests involved driving the vehicles along a straight-line path at 20 mph and quickly manually 'flicking' the handlebars and letting go of the handlebars. When the handlebars were flicked and released, the throttle levers were also released, causing the vehicles to naturally slow down after the rapid steering flick inputs.

The Steering Flick tests were used to evaluate the stability of the vehicles' responses to open-loop, free control steering inputs. An unstable vehicle may respond with unstable oscillatory or divergent behavior during a Steering Flick test. These tests indicate if a vehicle exhibits excessive oscillatory response to the flick input or if the vehicle responses do not return to a close-to-zero position after the steering is released (indicating too little self aligning steering moment or possibly too much friction in the steering system).

Detailed results from the Steering Flick tests are contained in Appendix C for the DPI loading tests and in Appendix D for the GVW loading tests.

3.6 Sinusoidal Sweep Steering (Frequency Response) Tests (15 mph)

The ATV ASC was used during the Sinusoidal Sweep Steering tests. These tests involved driving the vehicles at a nominal constant speed of 15 mph along an essentially straight-line path while steering in a sinusoidal manner with an ATV ASC steering amplitude of 5 deg, which generated nominally 0.1-0.3 g of lateral acceleration. The ATV ASC was commanded to sweep the steering input frequencies from 0.5 to 3.5 Hz over the course of 40 cycles. The duration of the ATV ASC steering input during these tests was close to 26 seconds to complete the 40 cycles.

The Sinusoidal Sweep Steering tests were done to investigate any issues that might result from exciting a resonant frequency in the vehicles' responses. These tests were also used to generate the lateral acceleration, roll angle, roll rate, and yaw rate frequency responses to steering inputs.

Detailed results from the Sinusoidal Sweep Steering tests are contained in Appendix C for the DPI loading tests and in Appendix D for the GVW loading tests.

4. DISCUSSION OF TEST RESULTS

Table 5 lists the appendices that contain test results. Appendix A contains tables with all of the results from the laboratory testing, with the exception of the graphs from the steering ratio tests conducted in the laboratory, which are contained in Appendix C. Appendix B contains a collection of bar charts, graphs, and tables summarizing selected results from both laboratory and dynamic testing. Detailed results from all of the dynamic testing conducted in the DPI loading condition are contained in Appendix C, and detailed results from all of the dynamic testing conducted in the GVW loading condition are contained in Appendix D.

Table 5: List of Appendices Containing Test Results

Appendix	Title
Appendix A	Laboratory Test Results
Appendix B	Summary Bar Charts, Graphs, and Tables
Appendix C	Results from Tests Conducted in the DPI Loading Condition
Appendix D	Results from Tests Conducted in the GVW Loading Condition

4.1 Discussion of Appendix A: Laboratory Test Results

Appendix A contains tabular results of laboratory measurements made by SEA. There are 24 pages of results, two pages for each vehicle. The first page for each vehicle contains a table of results from the VIMF and Steering Ratio tests, and the second page for each vehicle contains a table of results from the Tilt Table tests.

The first 19 rows of the first page contain quantities related to the mass (weight), track width, wheelbase, center-of-gravity location, and inertia measurements, as well as static rollover propensity calculations, based on measurements made using the VIMF. The final row contains the value for steering ratio, measured in the DPI loading condition.

The second page of tabular results for each vehicle lists the tilt table angles and tilt table ratios for the lateral and longitudinal Tilt Table tests conducted. These tables also list which wheel lifted first for each Tilt Table test; either Front or Rear for the lateral tilts and either Right or Left for the longitudinal tilts.

4.2 Discussion of Appendix B: Summary Bar Charts, Graphs, and Tables

The first 15 pages of Appendix B contain bar charts of vehicle Weight, Moment of Inertias, CG Height, Average Track Width, SSF, K_{ST}, Wheelbase, Longitudinal CG to Front Axle, Percent Weight on Front Axle, and Steering Ratio. As mentioned, Vehicles B, H and I were not tested in the GVW loading condition, so there are no bars shown in the bar charts for these test vehicles at GVW.

Pages 16 through 24 contain a collection of bar charts of results from the lateral Tilt Table tests.

Lateral TTR and TTA values are shown for Left Side Leading (driver's side leading), Right Side Leading (passenger's side leading), and Average (average of Left Side Leading and Right Side Leading). Page 25 contains a graph of TTR versus SSF for the Driver, DPI and GVW loading conditions.

Pages 26 through 29 contain bar charts of results from the longitudinal Tilt Table tests. The forward and rearward tilt ratios (FTTR and RTTR) and angles (FTTA and RTTA) are shown.

Page 30 contains a bar chart of the Threshold Lateral Acceleration (Threshold Ay) determined from the dynamic 20 mph Dropped Throttle J-Turn tests. Threshold Ay is the minimum peak lateral acceleration required to cause visual two-wheel lift during the J-Turn tests, and it is a metric that is used to categorize a vehicles tip-up or rollover resistance. The laboratory metrics Static Stability Factor (SSF) and Tilt Table Ratio (TTR) are also used to indicate a vehicles tip-up or rollover resistance. Page 31 contains a graph of SSF versus Threshold Ay for the DPI and GVW test conditions, and Page 32 contains a graph of TTR versus Threshold Ay for both loading conditions. Linear curve fits to the DPI and GVW data for both the SSF and TTR plots are shown on the graphs, and the quality of the correlations (expressed as R^2 values) between the linear curve fits and the underlying data are given in the graph legends. For the group of ATVs tested, the correlations between TTR and Threshold Ay are better than the correlations between TTR and Threshold Ay were for a group of 22 ROVs previously tests by CPSC.[9]

The Roll Gradients, the amount of roll angle in degrees per "g" of lateral acceleration, determined from the Circle tests are shown in the bar chart on Page 33 for both DPI and GVW loading conditions. The measured maximum speed of each vehicle in the DPI loading condition is shown on Page 34.

Page 35 (DPI loading condition) and Page 36 (GVW loading condition) each contain a table listing the CW (clockwise), CCW (counterclockwise), and Average values for the lateral accelerations at which the vehicles that transitioned from understeer to oversteer during the Circle tests did so. "NA" in the tables indicates that no transition to oversteer occurred.

For the DPI loading condition, Page 37 contains a table listing the Right Turn, Left Turn, and Average values for the lateral accelerations at which the vehicles that transitioned from understeer to oversteer during the SIS tests did so. "NA" in the table indicates that no transition to oversteer occurred.

Page 38 (DPI loading condition) and Page 39 (GVW loading condition) each contain a table summarizing the average minimum peak lateral accelerations (Threshold Ay values) during the 20 mph Dropped Throttle J-Turn tests.

Page 40 contains a table listing the Right Turn, Left Turn, and Average values for the final Yaw Rate Ratios determined from the Constant Steer (Yaw Rate Ratio) tests, which were conducted in the DPI loading condition. Page 41 is a bar chart of the Yaw Rate Ratio results.

[9] *Tilt Table Measurements on Twenty-Two Recreational Off-Highway Vehicles – Including Correlation with Measured Threshold Lateral Acceleration*, CPSC Contract CPSC-D-11-0003, SEA, Ltd. Report to CPSC, September 2015.
http://www.cpsc.gov/Global/Research-and-Statistics/Injury-Statistics/Sports-and-Recreation/ATVs/SEAReportTiltTableResults22ROVsSept2015.pdf

4.3 Discussion of Appendix C: Results from Tests Conducted in the DPI Loading Condition

Appendix C contains the graphical test results for all 12 vehicles tested in the DPI loading condition. All test results for each vehicle are presented together, in the following order:

- Constant Radius (50 ft) (Circle) Tests
- Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)
- Constant Speed (20 mph) Slowly Increasing Steer Tests
- Constant Steer Tests (Yaw Rate Ratio Tests)
- Steering Flick Tests (20 mph)
- Sinusoidal Sweep Steering (Frequency Response) Tests (15 mph)
- Steering Ratio Tests

Table 6 contains a table of contents for Appendix C, listing the pages containing results for each of the 12 vehicles.

Table 6: Appendix C Table of Contents

Vehicle	Page Numbers	Vehicle	Page Numbers
A	1-31	G	159-182
B	32-55	H	183-206
C	56-79	I	207-230
D	80-103	J	231-254
E	104-127	K	255-278
F	128-158	L	279-302

The discussion in this section will cover each test in the order listed above. A couple of general comments regarding the graphs presented for all test types are:

- The lateral accelerations shown on the graphs are the lateral accelerations parallel to the road plane, not the vehicle body-fixed lateral accelerations.
- The steering angles shown on the graphs are roadwheel steer angles, which are the measured steering column angles divided by the measured steering ratios. The measured steering ratios ranged from 1.21:1 to 1.62:1.
- The ATV ASC was used for the J-Turn, Slowly Increasing Steer (SIS), Sinusoidal Sweep Steering, and Yaw Rate Ratio tests. For tests using the ATV ASC, the commanded steering input is the input to the ATV ASC motor. The ATV ASC steering angle and the steering column angle are not exactly one-to-one, due to compliance in the ATV ASC four-bar linkage arrangement, its motor base mounting to the vehicles, and the

handlebars. ATV ASC steering angles are not shown on the graphs; instead the roadwheel steer angles are used since they are based on the directly measured steering column angles.

4.3.1 DPI Constant Radius (50 ft) (Circle) Tests

For each vehicle there are four pages showing results from both the clockwise (CW) and counterclockwise (CCW) Circle tests. The first page shows time domain plots of Roadwheel Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate. All of the dynamic test data is sampled at 100 Hz. For the Circle test results, the data shown was digitally low-pass filtered to 1.0 Hz using a phaseless, eighth-order, Butterworth filter. The time domain data shown for each vehicle contains all of the data from the time the test driver started the data acquisition (prior to starting to move on the circle) to the time the test driver ended the data acquisition at the end of the test. The test drivers intended to drive the vehicles to a lateral acceleration level of at least 0.4 g, and the driver-alert light was set to a value slightly above 0.4 g. However, some vehicles did not achieve 0.4 g of lateral acceleration because they started to tip-up below 0.4 g, at which time the test driver ended the test.

On the first page of Circle test graphs for each vehicle, the thin black lines for the CW and CCW tests show the full range of data collected. The thicker lines (red for CW and blue for CCW) indicate the range of data used to fit the subsequent understeer and roll gradient characteristic curves. These ranges all start from the time the vehicle attained a speed of 2.7 mph, which is a lateral acceleration of 0.01 g on a 50 ft radius circle. For most vehicles, the range ends when the vehicle attained a speed of 17.3 mph, which is a lateral acceleration of 0.40 g on a 50 ft radius circle. For vehicles that did not reach a speed of 17.3 mph (or a lateral acceleration of 0.4 g), the range ends when the vehicle reached it maximum speed during the test. This nominal range of data, from 0.01 g to 0.40 g, was selected because it provided a consistent range of lateral accelerations over which meaningful curve fits of the data could be made. The speed plots show that the Circle tests were conducted using a very slow rate of increase in speed during the circle tests. Regarding conducting circle tests for passenger vehicles, SAE J266[10] states: “If speed is steadily increased, the rate of increase shall not exceed 1.5 km/h per second (0.93 mph per second), and data shall be recorded continuously, so long as the vehicle remains on radius.” The rates of speed increase during the Circle tests conducted are less than the J266 recommended maximum rate.

There is one exception to the range selection method described above, and it is for Vehicle F (Pages 128-131). Vehicle F transitioned from understeer to oversteer in the range of 0.12-0.14 g, and then transitioned back to understeer when the lateral acceleration exceeded 0.3 g. This phenomenon – going from understeer to oversteer and then back to understeer – is not a typical response for four-wheeled vehicles. This phenomenon also occurred for Vehicle F and other vehicles in the SIS and Yaw Rate Ratio tests, and the reason(s) for it occurring on some ATVs is under study. For Vehicle F, the range of data selected to fit the characteristic curves was ended at 0.33 g. The figures on Pages 129-131 show the curve fits over the ranges selected for Vehicle F.

The second page for each vehicle shows graphs of Roadwheel Steer Angle versus Ay (lateral

[10] SAE Surface Vehicle Recommended Practice - Steady-State Directional Control Test Procedures For Passenger Cars and Light Trucks, SAE J266, 1996.

acceleration). The CW test results are in the upper right quadrants of the graphs and the CCW test results are in the lower left quadrants of the graphs. The thin red lines show data in the range of vehicle speeds from 2.7 mph to the maximum speed achieved during each test. For both the CW and CCW data, there is a thicker blue line indicating second-order polynomial curve fits to the range of data selected, as described above. The red circles on these graphs are the geometric Ackermann steer angles, a function of the steering ratio (K) times the wheelbase (L) divided by the circle radius (R), given by:

$$\delta_{SW\ (\text{Geometric Ackermann})} = \frac{(180/\pi) \times K \times L}{R}$$

The geometric Ackermann steer angles are not the same as the actual roadwheel steer angles required to negotiate the circles at very low speed, with Ay close to zero. The actual roadwheel steer angles, which can be referred to as the measured Ackermann steer angles, are generally greater than the geometric Ackermann steer angles due primarily to compliance and lash in the steering system, and compliance in the suspension systems and tires.

The third page for each vehicle contains a graph of Roadwheel Steer Angle minus (measured) Ackermann Angle versus Ay (lateral acceleration). For these graphs, the signs of the CCW data are reversed so that the CW and CCW results can be directly compared. The thin lines show data in the range of data selected for each vehicle as described above, and the thick lines are the second-order polynomial curve fits to the data. Notice that the measured Ackermann steer angles are the abscissae of the curve fits taken at Ay equal to zero, so the curve fits tend to zero as Ay goes to zero. For a circle test: understeer can be defined as the condition when the steering input required to maintain the circular path increases as the vehicle speed increases, neutral steer can be defined as the condition when the steering input required to maintain the circular path does not change as the vehicle speed increases, and oversteer can be defined as the condition when the steering input required to maintain the circular path decreases as the vehicle speed increases. The second-order polynomial curve fits do a good job of representing the underlying data whether the particular test vehicle exhibits understeer, neutral steer, or oversteer characteristics during the Circle tests.

All of the vehicles tested exhibit understeer at low levels of lateral acceleration and then all of the vehicles except Vehicles D and E transition to oversteer at higher levels of lateral acceleration. The points of transition from understeer to oversteer are indicated on the graphs by black circles, and they are mathematically the points where the slopes of the curve fits change from being positive to negative. For circle tests where the vehicles exhibited a transition from understeer to oversteer, the values of the lateral acceleration at the points of transition are indicated on the graphs.

The fourth page for each vehicle contains a graph of Roll Angle versus Ay (lateral acceleration). The CW test results are in the lower right quadrants of the graphs and the CCW test results are in the upper left quadrants of the graphs. The thin lines show data in the range of vehicle speeds from 4.0 mph to the maximum speed achieved during each test. The thick lines are linear curve fits to the CW and CCW data over the ranges of data selected, as described above. The average of the CW and CCW curve fit slopes are listed on the graphs as the Roll Gradient.

Page 35 of Appendix B contains a summary table of the CW, CCW, and Average lateral acceleration levels at which the vehicles that transitioned from understeer to oversteer did so during the DPI Circle tests. “NA” in the table indicates that no transition to oversteer occurred. Page 33 of Appendix B contains a bar chart showing the Roll Gradients measured during the Circle tests.

4.3.2 DPI Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)

For each vehicle there are five pages of results for the Dropped Throttle J-Turn tests. The first four pages show time domain plots for the tests. The first and third pages for each vehicle show plots of Roadwheel Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate; for the 10 Northbound and the 10 Southbound runs, respectively. The second and forth pages for each vehicle show larger plots of Lateral Acceleration; for the 10 Northbound and 10 Southbound runs, respectively. For the J-Turn test results, the data shown was digitally low-pass filtered to 2.0 Hz using a phaseless, eighth-order, Butterworth filter. The time domain data shown for each vehicle contains data from 0.5 seconds before the ATV ASC steering input was applied until 5.0 seconds after it was applied.

For each vehicle, the plots contain results from five Northbound right steer J-Turns, five Northbound left steer J-Turns, five Southbound right steer J-Turns, and five Southbound left steer T-turns. In all cases, the plots contain results for tests that resulted in visually determined two-wheel lift. An SAE standard sign convention is used, with Roadwheel Steer Angle, Lateral Acceleration, and Yaw Rate being positive for right turns and Roll Angle being negative for right turns.

The fifth page shown for each vehicle contains a summary of the peak lateral accelerations measured in each test. These values are the maximum values of lateral acceleration shown on the plots, which contain data that has been filtered to 2.0 Hz.

The summary pages show the peak lateral accelerations for the five runs conducted in the Northbound right steer direction, Northbound left steer direction, Southbound right steer direction, and Southbound left steer direction. The mean values and standard deviations from each of the five sample runs are shown on the summary pages. Also, the average of the ten Northbound and Southbound runs is shown, as is the average of all 20 runs, which is the Threshold Ay value.

Page 38 of Appendix B contains a table listing the DPI loading Threshold Ay values for each vehicle.

4.3.3 DPI Constant Speed (20 mph) Slowly Increasing Steer Tests

For each vehicle there are two pages showing results from both the right turn and left turn Slowly Increasing Steer (SIS) tests. The first page shows time domain plots of Roadwheel Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate. For the SIS test results, the data shown was digitally low-pass filtered to 5.0 Hz using a phaseless, eighth-order, Butterworth filter. The time domain data shown for each vehicle contains data from 0.5 seconds before the ATV ASC steering input was applied until the time the test driver ended the test (the thin black lines).

During these SIS tests, the driver tried to maintain a constant speed of 20 mph and the ATV ASC was programmed to apply a slow steering input at the rate of 2.0 deg/sec. The thicker lines (red for right turns and blue for left turns) indicate the range of data from time equal zero to a time near when the vehicle reached its maximum lateral acceleration during the test.

The second page for each vehicle contains a graph of Roadwheel Steer Angle versus Lateral Acceleration (Ay). The right turn test results are in the upper right quadrants of the graphs and the left turn test results are in the lower left quadrants of the graphs. The red and blue lines show data from time equal zero to a time near when the vehicle reached its maximum lateral acceleration during the test. Except for Vehicles A and F, the black lines are fifth-order polynomial curve fits to the data in the range from time (and Ay) equal to zero to a time when the lateral acceleration reached 0.4 g or above (the end points of the data ranges were judiciously selected so that the curve fits would best match the underlying data). The black fit lines are extended to 0.4 g, except for Vehicles A and F. The fifth-order polynomial curve fits do a good job of representing the underlying data from the SIS tests.

Vehicles A and F exhibit the phenomenon of going from understeer to oversteer and then back to understeer, all at lateral acceleration levels less than 0.4 g. In these cases, the curve fit ranges used were terminated where the responses transitioned from oversteer back to understeer. The end values of 0.35 g for Vehicle A and 0.325 g for Vehicle F were used, and they provided the curve fits shown on Pages 11 and 138 of Appendix C.

The green lines on the second page graphs are the Ackermann steer angle gradients, a function of the wheelbase (L) divided by the vehicle speed (V) squared, given by:

$$\text{Ackermann Steer Angle Gradient} = \frac{g \times (180/\pi) \times L}{V^2}$$

where “g” is the Gravitational Constant.

When plotted on the graphs of data from a constant speed SIS test, Ackermann steer angle gradients represent neutral steer. Conditions when the slope of the characteristic curve is greater than the Ackermann steer angle gradient represent understeer and conditions when the slope of the characteristic curve is less than the Ackermann steer angle gradient represent oversteer. For vehicles that transitioned to Oversteer, the points during the tests where the vehicles transitioned (the points where the slope of the characteristic curve equals the slope of the Ackermann steer angle gradient) are indicated on the graphs by a black circle. Also, the lateral accelerations where the transition to oversteer occurred are listed on the graphs.

Page 37 in Appendix B contains a summary table of the Right Turn, Left Turn, and Average lateral acceleration levels at which the vehicles transitioned from understeer to oversteer. “NA” in the tables indicates that no transition to oversteer occurred.

4.3.4 DPI Constant Steer Tests (Yaw Rate Ratio Tests)

There are seven pages of Constant Steer test results for each condition used to compute the Yaw Rate Ratios. As was the case for the SIS tests, Vehicles A and F exhibited the phenomenon of going from understeer to oversteer and then back to understeer, all at lateral acceleration levels less than 0.4 g. For these two vehicles, there are two sets of seven page test results, one set using the final data range of 0.3-0.4 g, and one using a lower range that extends only to the point where the vehicles transitioned from oversteer back to understeer.

The first page shows time domain plots of Roadwheel Steer Angle, Estimated Ay (Estimated Lateral Acceleration), Speed, Roll Angle, and Yaw Rate. There are plots for the five right direction steer tests (CW tests) and for the five left direction steer tests (CCW tests). For all of the graphs from the Constant Steer tests, the Roadwheel Steer Angle data shown was digitally low-pass filtered to 10.0 Hz using a phaseless, eighth-order, Butterworth filter; and the Estimated Ay data shown was digitally low-pass filtered to 1.0 Hz using a phaseless, eighth-order, Butterworth filter. The Speed, Roll Angle and Yaw Rate data shown is unfiltered.

The second page of results from the Constant Steer tests contains the plots of Estimated Ay versus Speed for all ten tests.

The third page of results contains the plot of Yaw Rate versus Speed for all ten tests, and this is the graph that also shows the slope values for the individual test run initial and final ranges (and their standard deviations), the individual test run CW and CCW slope ratios (and their standard deviations), the average CW and CCW slope ratios (the Yaw Rate Ratios), and the final average of the CW and CCW slope ratios (the Average Ratio). All of the linear curve fits in the initial and final ranges are shown, and the thick black lines indicate where combinations of yaw rate and speed equal 0.4 g of lateral acceleration.

The following steps were taken to compute the slopes and Yaw Rate Ratios contained on the third page graphs:

1. For each test run, to determine the data regions for analysis, the yaw rate and speed channels were filtered using a low-pass Butterworth filter with a cut-off frequency of 1 Hz. Then the estimated lateral acceleration in units of “g’s” was computed using the following equation:

$$\text{Estimated } A_y = \frac{\pi}{180} \times \frac{\text{Yaw Rate} \times \text{Speed}}{32.2}$$

   where Yaw Rate is in deg/sec and Speed is in ft/sec.

   The protocol used to compute Estimated Ay is the same as the protocols contained in ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016.[11]

[11] The equations given in ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 to compute Estimated Ay differ from the equation listed above because metric dimensions are used in the voluntary standards. However, all of the equations compute Estimated Ay in units of “g’s”, by dividing by the gravitational constant defined as 9.8 m/s^2 or 32.2 ft/s^2.

2. The estimated lateral acceleration, Estimated A_y, was used to determine the start and stop points for the following regions:

    a. The Initial Region is from 0.1 to 0.2 g.
    b. The Final Region is from 0.3 to 0.4 g.[12]

3. For each test run, in both the initial and final regions, linear slopes of unfiltered yaw rate versus data index and linear slopes of unfiltered speed versus data index were computed.[13] The slopes can be classified as:

    a. Y1 = linear slope of the yaw rate versus index plot for Initial Region
    b. Y2 = linear slope of the yaw rate versus index plot for Final Region
    c. V1 = linear slope of the vehicle speed versus index plot for Initial Region
    d. V2 = linear slope of the vehicle speed versus index plot for Final Region

4. The Yaw Rate Ratio (R) for each run was then computed using the following equation:

$$\text{Yaw Rate Ratio (R)} = \frac{\left(\frac{Y2}{V2}\right)}{\left(\frac{Y1}{V1}\right)}$$

5. Steps 1 through 4 were then repeated for all ten test runs.

6. The following final slope ratios were then computed:

    a. Right Turn Yaw Rate Ratio (CW Average) = Average of the 5 right turn test runs
    b. Left Turn Yaw Rate Ratio (CCW Average) = Average of the 5 left turn test runs
    c. Average Yaw Rate Ratio (Average Ratio) = Average of the Right Turn and Left Turn Yaw Rate Ratios

The forth and fifth pages for each test condition contain magnified sections of the individual final slope regions for the right turn (CW) and left turn (CCW) runs, respectively. These graphs also contain black lines indicating where combinations of yaw rate and speed equal 0.4 g of lateral acceleration. A vehicle with severe oversteer in the final slope region will have a steep slope (high Final Slope value), and this will produce a high Yaw Rate Ratio. Steep final slopes are indicative of divergent vehicle behavior, a condition when the yaw rate and lateral acceleration gains are high and the vehicle is prone to yaw and/or tip-up instability.

The sixth and seventh pages show individual path plots for the right turn (CW) and left turn (CCW) runs, respectively. As speed is increased during a Constant Steer tests, an understeering vehicle will travel on a path of increasing radius, and an oversteering vehicle will travel on a path

[12] The ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 protocols use a final range of 0.4-0.5 g for ROVs. For the ATVs tested in this case, the final range of 0.3-0.4 g was used. Also, as in ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016, a contiguous region of Estimated A_y was used for the final range of data.

[13] The ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 protocols specify computing slopes as versus *time*. Given the form of the final computation for Yaw Rate Ratio, computing the slopes versus *time* or versus *data index* result in the same answer for Yaw Rate Ratio.

of decreasing radius. The path plot graphs have green, red, and black line portions, indicating ranges of lateral acceleration during the runs. The initial regions are shown with the green lines and the final regions are shown with the red lines.

Vehicles D and E were the most understeering vehicles tested; they were the only vehicles that did not transition to oversteer during any of the Circle or SIS tests conducted. During Constant Steer tests starting on a 50 ft radius path, both of these vehicles tended to a large-radius path that would have taken them off of the test pad area. Therefore, per the test protocol, a 25 ft radius initial path was used to test these two vehicles.

As mentioned, Vehicles A and F exhibit the phenomenon of going from understeer to oversteer and then back to understeer, all at lateral acceleration levels less than 0.4 g. Because they transitioned to understeer prior to achieving 0.4 g of lateral acceleration, they also tended off of the test pad area when tested using a 50 ft radius initial path. Therefore, these two vehicles were also tested using a 25 ft radius initial path.

For Vehicles A and F, there are two sets of seven-page results for the Constant Steer tests. The two sets of results for each have the same data, but for the second set for each vehicle a different region of data is used to compute the final slopes, and the Yaw Rate Ratios are recomputed using these final slopes. The first set of results use the final region that was used for all vehicles, 0.3-0.4 g. The second set of reprocessed results uses a different final region that extends up to the point were the vehicles transitioned from oversteer back to understeer (referred to here as the inflection point). The final slope range used for Vehicle A was 0.27-0.32 g and the final slope range used for Vehicle F was 0.26-0.31 g. For these sets of results using the inflection point as the maximum Estimated Ay, graphs of Yaw Rate versus Speed contain black lines indicating where combinations of yaw rate and speed equal the maximum Estimated Ay: 0.32 g for Vehicle A and 0.31 g for Vehicle F.

Using the final region of 0.3-0.4 g, which is mostly in the understeer range for these vehicles, results in low Yaw Rate Ratios for these vehicles. Page 14 of Appendix A shows that the CW Average is 0.411 and the CCW Average is 0.287 for Vehicle A. The red lines on Pages 17 and 18 show that the path radius of Vehicle A increases significantly in this range of lateral accelerations. When the oversteering regions leading up to the inflection points are used, 0.27-0.32 g for Vehicle A, the computed Yaw Rate Ratios are greater, with a CW Average of 1.73 and a CCW Average of 2.50 (as shown on Page 21). The red lines on Pages 24 and 25 show that the path radius of Vehicle A decreases in this range of lateral accelerations prior to the inflection point, when the vehicle is oversteering.

Page 40 in Appendix B contains a summary table of the Right Turn (CW), Left Turn (CCW), and Average Yaw Rate Ratios computed from the Constant Steer tests. The values for all 12 vehicles using a final slope region of 0.3-0.4 g of lateral acceleration are given, as are the reprocessed values for Vehicles A and F using final slope regions up the inflection points as discussed above. Page 41 in Appendix B is a bar chart of the Yaw Rate Ratio results given in the table on Page 40 in Appendix B.

The ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 criteria for passing their constant steer handling test using an ROV is that neither the right turn Yaw Rate Ratio nor the left turn Yaw Rate Ratio exceeds 4.5.

4.3.5 DPI Steering Flick Tests (20 mph)

For each vehicle there are two pages showing time domain plots for the Steering Flick tests, with the first page showing results from a right steering test and the second page showing results from a left steering test. Each of these pages shows plots of Roadwheel Steer Angle, Speed, Lateral Acceleration, Roll Angle, and Yaw Rate. The drivers were instructed to "flick" the handlebars and let go of them. The measured magnitudes of the flicks ranged from about 7-15 degrees of roadwheel steer angle (the handlebar steer angle magnitudes were greater than these values).

For the Steering Flick test results, the data shown was digitally low-pass filtered to 5.0 Hz using a phaseless, eighth-order, Butterworth filter. With two exceptions, the time domain data shown for each vehicle and configuration contains data for 3.5 seconds, commencing 0.5 seconds prior to the start of the steering input. The exceptions are for Vehicles E and G, where the data is plotted for 4.5 seconds to span the time range needed for the vehicle responses to settle towards zero.

For all of the vehicles, the steering and vehicle responses returned to their zero values, and they did not exhibit any divergent behavior. It is important to point out that when the handlebars were flicked and released, the throttle levers were also released, so the vehicles immediately started slowing down as soon as the steering was flicked. Except for Vehicles E and G, the vehicles' responses returned to their near zero values within one to a few cycles of oscillation. Vehicle E responses oscillated about 12 cycles and Vehicle G oscillated about 15 cycles. All of the vehicles' responses were damped and stable.

4.3.6 DPI Sinusoidal Sweep Steering (Frequency Response) Tests (15 mph)

For each vehicle there are three pages of results. The first page of results for each vehicle contains representative time domain plots for one of the sinusoidal sweep tests conducted. Each of these pages shows time domain plots of Roadwheel (Steer Angle), Ay (Lateral Acceleration), Roll Angle, Roll Rate, and Yaw Rate. The data shown was digitally low-pass filtered to 10.0 Hz using a phaseless, eighth-order, Butterworth filter.

The steering inputs used during the sinusoidal sweeps provided for meaningful frequency response computations in the range of 0.5 to 3.0 Hz. The frequency responses were computed using the transfer function estimator routine in Matlab. The second page of graphs for each vehicle contains frequency response plots of amplitude ratio and phase angle for lateral acceleration and roll angle frequency responses to steering input. The third page of graphs for each vehicle contains frequency response plots for roll rate and yaw rate. On each of the frequency response plots, results from two or three tests are shown.

Based on linear vehicle response theory, the low frequency values of the amplitude ratios (magnitudes) for lateral acceleration, roll angle, and yaw rate represent the steady state gains that a vehicle would have achieved if it was driven at a low (linear range) lateral acceleration steady state condition (The steady state gain for roll rate is zero.). Most of the lateral acceleration, roll angle and yaw rate frequency responses exhibited underdamped behavior; that is, the amplitude ratios (magnitudes) are greater at higher frequencies than they are at low frequency (i.e. their steady state gain values). This behavior is not unusual for automotive passenger vehicles, and it is generally not indicative of any problem unless the amplitude ratios are considerably higher at some frequencies than they are at steady state. In instances where the amplitude ratios become excessively high at higher frequencies, a driver might not be aware of increasing vehicle response under rapid steering conditions. Based on the frequency responses generated from this testing, this does not appear to be an issue for any of the vehicles tested. However, note that the frequency responses are computed from testing done at low lateral acceleration levels, and they can not be used to infer anything about the vehicles' responses at lateral accelerations above about 0.3 g, or anything about the vehicles' tip-up resistances or understeer/oversteer characteristics.

Overall, the time domain and frequency response curves generated did not indicate any anomalous vehicle behavior. For all of the tests conducted, the vehicles were responsive to the steering inputs and remained stable for the sweep of steering inputs applied.

4.3.7 DPI Steering Ratio Tests

The final page presented for each vehicle contains results from the Steering Ratio tests. The top graph on each page plots data taken from the right wheel and the bottom graph plots data from the left wheel. The plots also show blue linear curve fits to the data in the range of ±10° of steering column angle. The Right Steering Ratio, the Left Steering Ratio, and the Average Steering Ratio are presented on the plots. Page 15 of Appendix B contains a bar chart showing the Steering Ratios measured during the Steering Ratio tests.

4.4 Discussion of Appendix D: Results from Tests Conducted in the GVW Loading Condition

Appendix D contains the graphical test results for all nine vehicles tested in the GVW loading condition. All test results for each vehicle are presented together, in the following order:

- Constant Radius (50 ft) (Circle) Tests
- Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)
- Steering Flick Tests (20 mph)
- Sinusoidal Sweep Steering (Frequency Response) Tests (15 mph)

Table 7 contains a table of contents for Appendix D, listing the pages containing results for each of the nine vehicles.

Table 7: Appendix D Table of Contents

Vehicle	Page Numbers	Vehicle	Page Numbers
A	1-14	G	71-84
C	15-28	J	85-98
D	29-42	K	99-112
E	43-56	L	113-126
F	57-70		

4.4.1 GVW Constant Radius (50 ft) (Circle) Tests

The same data processing that was used for the DPI Circle tests was used for the GVW Circle tests, and the same set of four pages of results are given for the GVW loading tests as were given for the DPI loading tests.

During the GVW Circle tests, Vehicle F again transitioned from understeer to oversteer and then back to understeer, like it did in the DPI Circle test. For the Vehicle F GVW Circle tests, the range of data selected to fit the characteristic curves was ended at 0.30 g (see Pages 57-60 of Appendix D).

Page 36 of Appendix B contains a summary table of the CW, CCW, and Average lateral acceleration levels at which the vehicles that transitioned from understeer to oversteer did so during the GVW Circle tests. “NA” in the table indicates that no transition to oversteer occurred. The two vehicles that remained understeering throughout the GVW loading Circle tests, Vehicles D and E, were the same two vehicles that remained understeering in the DPI loading Circle tests. All of the vehicles, except for Vehicle L, that transitioned to oversteer during the circle tests, do so at slightly lower lateral accelerations level during the GVW Circle tests than they did during the DPI Circle tests. Vehicle L transitioned to oversteer at a slightly higher lateral acceleration level during the GVW Circle tests than it did during the DPI Circle tests.

Page 33 of Appendix B contains a bar chart showing the Roll Gradients measured during the Circle tests. For all of the vehicles, the Roll Gradients measured during the GVW Circle tests are greater than the Roll Gradients measured during the DPI Circle tests.

4.4.2 GVW Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)

The same data processing that was used for the DPI J-Turn tests was used for the GVW J-Turn tests, and the same set of five pages of results are given for the GVW loading tests as were given for the DPI loading tests. However, for the GVW J-Turn tests, only three visual two-wheel lift test outcomes in each heading and turn direction were conducted; instead of five that were used in the DPI J-Turn tests.

Page 39 of Appendix B contains a table listing the GVW loading Threshold Ay (based on 12 visual two-wheel lift runs for the GVW J-Turn tests) values for each vehicle. For all of the vehicles, the Threshold Ay values measured during the GVW loading J-Turn tests are lower than those measured during the DPI loading J-Turn tests.

4.4.3 GVW Steering Flick Tests (20 mph)

The drivers intended to input the same level of steering flick during the GVW Steering Flick tests as they did during the DPI Steering Flick tests, and the range of roadwheel steering magnitudes for the GVW tests are comparable to those used during the DPI tests. The same data processing that was used for the DPI Flick tests was used for the GVW Flick tests; and the same set of two pages of results are given for the GVW loading tests as were given for the DPI loading tests.

With two exceptions, the time domain data shown for each vehicle contains data for 3.5 seconds, commencing 0.5 seconds prior to the start of the steering input. The exceptions are for Vehicles E and G, where the plot ranges are extended to show the ranges of time needed for the vehicle responses to settle towards zero (4.5 seconds for Vehicle E and 6.5 seconds for Vehicle G).

The vehicle responses were generally more oscillatory during the GVW Flick tests than they were during the DPI Flick tests. For all of the vehicles, the steering and vehicle responses returned to their zero values, and they did not exhibit any unstable divergent behavior.

Like they did during the DPI Flick tests, Vehicle E and G oscillated the most during the GVW Flick tests, and again Vehicle E responses oscillated about 12 cycles and Vehicle G oscillated about 15 cycles. In the GVW loading condition, Vehicle G had 9-10 oscillations with roadwheel steering magnitudes greater then the initial flick magnitude (Vehicle G had only one half-cycle of roadwheel steering magnitude greater than the initial steering magnitude in the DPI Flick tests). Vehicle G had more oscillations during the Flick tests than any of the other vehicles, and it is the only vehicle that had cycles of steering with greater magnitude than the initial flick steering angle.

4.4.4 GVW Sinusoidal Sweep Steering (Frequency Response) Tests (15 mph)

The same data processing was used for the GVW Sinusoidal Sweep Steering tests as was used for the DPI Sinusoidal Sweep Steering tests, and the same set of three pages of results are given for the GVW loading tests as were given for the DPI loading tests.

For all of the vehicles, the peaks that occurred in the lateral acceleration, roll angle, roll rate and yaw rate frequency responses generally all occurred at lower frequencies when the vehicles were loaded to GVW than when they were loaded to DPI. Overall, the time domain and frequency response curves generated from the Sinusoidal Sweep Steering tests did not indicate any anomalous vehicle behavior. For all of the tests conducted, the vehicles were responsive to the steering inputs and remained stable for the sweep of steering inputs applied.

Vehicle A

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5765	5766	5842
Total Vehicle Weight (lb)	523.9	737.1	759.6	989.7
Left Front Weight (lb)	151.5	177.3	198.3	232.2
Right Front Weight (lb)	118.4	161.0	176.8	212.1
Left Rear Weight (lb)	132.0	206.1	204.4	293.5
Right Rear Weight (lb)	122.0	192.7	180.1	251.9
Front Track Width (in)	33.20	33.50	33.66	33.93
Rear Track Width (in)	32.25	32.30	32.28	32.35
Average Track Width (in)	32.73	32.90	32.97	33.14
Wheelbase (in)	48.40	48.35	48.30	48.25
CG Longitudinal (in)	23.47	26.16	24.45	26.59
CG Lateral (in)	-1.36	-0.66	-0.99	-1.02
CG Height (in)		23.61	22.65	25.00
Roll Inertia - I_{XX} (ft-lb-s^2)		55	66	86
Pitch Inertia - I_{YY} (ft-lb-s^2)		73	80	141
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		54	63	115
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	3	8
SSF		0.697	0.728	0.663
KST		0.698	0.728	0.664
Steering Ratio (deg/deg)			1.42	

Vehicle A

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	27.4	25.9	21.3
	Tilt Table Ratio (TTR)	0.519	0.486	0.391
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	25.8	25.4	20.1
	Tilt Table Ratio (TTR)	0.482	0.474	0.365
	Average Lateral TTA (deg)	**26.6**	**25.6**	**20.7**
	Average Laleral TTR	**0.501**	**0.480**	**0.378**

Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Left	Right
	Forward Tilt Table Angle (FTTA) (deg)	47.5	46.5	44.3
	Forward Tilt Table Ratio (FTTR)	1.091	1.052	0.975

Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Right	Right	Right
	Rearward Tilt Table Angle (RTTA) (deg)	41.3	45.7	41.4
	Rearward Tilt Table Ratio (RTTR)	0.880	1.024	0.882

Vehicle B

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5768	5769	
Total Vehicle Weight (lb)	432.8	644.9	689.6	
Left Front Weight (lb)	117.8	144.0	174.5	
Right Front Weight (lb)	101.4	130.9	156.6	
Left Rear Weight (lb)	107.7	181.7	172.0	
Right Rear Weight (lb)	105.9	188.3	186.5	
Front Track Width (in)	37.78	38.13	38.45	
Rear Track Width (in)	35.58	35.50	35.40	
Average Track Width (in)	36.68	36.81	36.93	
Wheelbase (in)	50.30	50.85	50.85	
CG Longitudinal (in)	24.82	29.17	26.44	
CG Lateral (in)	-0.79	-0.21	-0.13	
CG Height (in)		22.77	22.34	
Roll Inertia - I_{XX} (ft-lb-s^2)		48	48	
Pitch Inertia - I_{YY} (ft-lb-s^2)		61	71	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		42	56	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	4	
SSF		0.808	0.826	
KST		0.813	0.828	
Steering Ratio (deg/deg)			1.34	

Vehicle B

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	
	Tilt Table Angle (TTA) (deg)	31.0	31.7	
	Tilt Table Ratio (TTR)	0.601	0.617	
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	
	Tilt Table Angle (TTA) (deg)	32.0	32.3	
	Tilt Table Ratio (TTR)	0.625	0.631	
	Average Lateral TTA (deg)	**31.5**	**32.0**	
	Average Laleral TTR	**0.613**	**0.624**	

Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Left	
	Forward Tilt Table Angle (FTTA) (deg)	49.4	48.4	
	Forward Tilt Table Ratio (FTTR)	1.166	1.125	

Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Right	Right	
	Rearward Tilt Table Angle (RTTA) (deg)	41.4	42.6	
	Rearward Tilt Table Ratio (RTTR)	0.882	0.918	

Vehicle C

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5771	5772	5844
Total Vehicle Weight (lb)	650.8	863.6	885.0	1135.1
Left Front Weight (lb)	175.1	208.3	224.7	251.5
Right Front Weight (lb)	163.9	199.5	221.9	245.1
Left Rear Weight (lb)	155.9	231.6	225.7	317.5
Right Rear Weight (lb)	155.9	224.2	212.7	321.0
Front Track Width (in)	39.71	39.95	39.95	40.10
Rear Track Width (in)	37.66	38.40	38.45	38.85
Average Track Width (in)	38.69	39.18	39.20	39.48
Wheelbase (in)	49.33	49.30	49.30	49.30
CG Longitudinal (in)	23.63	26.02	24.42	27.73
CG Lateral (in)	-0.34	-0.37	-0.35	-0.05
CG Height (in)		23.74	22.97	25.50
Roll Inertia - I_{XX} (ft-lb-s^2)		75	78	109
Pitch Inertia - I_{YY} (ft-lb-s^2)		92	101	174
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		72	83	147
Roll/Yaw - I_{XZ} (ft-lb-s^2)		7	5	18
SSF		0.825	0.853	0.774
KST		0.826	0.853	0.776
Steering Ratio (deg/deg)			1.62	

Vehicle C

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	31.1	30.6	26.0
	Tilt Table Ratio (TTR)	0.603	0.592	0.488
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	31.2	31.1	25.7
	Tilt Table Ratio (TTR)	0.605	0.604	0.481
	Average Lateral TTA (deg)	**31.1**	**30.9**	**25.9**
	Average Laleral TTR	**0.604**	**0.598**	**0.485**

Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Left	Left
	Forward Tilt Table Angle (FTTA) (deg)	48.5	47.6	44.5
	Forward Tilt Table Ratio (FTTR)	1.131	1.097	0.984

Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Right	Right	Right
	Rearward Tilt Table Angle (RTTA) (deg)	45.1	47.2	39.8
	Rearward Tilt Table Ratio (RTTR)	1.004	1.080	0.833

Vehicle D

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5774	5775	5845
Total Vehicle Weight (lb)	714.0	927.4	948.8	1227.9
Left Front Weight (lb)	179.9	216.3	234.7	268.9
Right Front Weight (lb)	169.7	205.7	223.9	269.9
Left Rear Weight (lb)	181.7	254.2	246.6	352.7
Right Rear Weight (lb)	182.7	251.2	243.6	336.4
Front Track Width (in)	39.46	39.90	39.99	40.40
Rear Track Width (in)	38.08	38.88	38.85	39.64
Average Track Width (in)	38.77	39.39	39.42	40.02
Wheelbase (in)	50.05	49.88	49.90	50.00
CG Longitudinal (in)	25.54	27.18	25.78	28.06
CG Lateral (in)	-0.26	-0.29	-0.29	-0.25
CG Height (in)		24.14	23.54	26.27
Roll Inertia - I_{XX} (ft-lb-s^2)		75	74	119
Pitch Inertia - I_{YY} (ft-lb-s^2)		108	114	200
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		88	99	170
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	6	16
SSF		0.816	0.837	0.762
KST		0.817	0.838	0.763
Steering Ratio (deg/deg)			1.22	

Vehicle D

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Front	Front	Front
	Tilt Table Angle (TTA) (deg)	32.0	32.8	26.9
	Tilt Table Ratio (TTR)	0.625	0.644	0.508
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Front	Front	Front
	Tilt Table Angle (TTA) (deg)	32.6	33.3	27.1
	Tilt Table Ratio (TTR)	0.638	0.657	0.512
	Average Lateral TTA (deg)	**32.3**	**33.0**	**27.0**
	Average Laleral TTR	**0.632**	**0.650**	**0.510**

Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Left	Left
	Forward Tilt Table Angle (FTTA) (deg)	49.0	47.9	45.6
	Forward Tilt Table Ratio (FTTR)	1.150	1.106	1.020

Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Left	Left	Left
	Rearward Tilt Table Angle (RTTA) (deg)	46.1	47.5	40.5
	Rearward Tilt Table Ratio (RTTR)	1.040	1.091	0.853

Vehicle E

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5777	5778	5846
Total Vehicle Weight (lb)	734.1	947.6	968.9	1248.5
Left Front Weight (lb)	190.3	221.1	245.4	277.0
Right Front Weight (lb)	168.5	210.1	220.9	260.1
Left Rear Weight (lb)	186.9	260.3	251.7	357.8
Right Rear Weight (lb)	188.4	256.1	250.9	353.6
Front Track Width (in)	39.48	39.80	40.05	40.50
Rear Track Width (in)	38.13	39.05	39.20	39.80
Average Track Width (in)	38.80	39.43	39.63	40.15
Wheelbase (in)	49.95	49.95	49.95	49.95
CG Longitudinal (in)	25.54	27.22	25.91	28.46
CG Lateral (in)	-0.55	-0.32	-0.52	-0.34
CG Height (in)		23.70	23.12	26.24
Roll Inertia - I_{XX} (ft-lb-s^2)		72	76	125
Pitch Inertia - I_{YY} (ft-lb-s^2)		108	116	201
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		95	100	169
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	6	20
SSF		0.832	0.857	0.765
KST		0.832	0.857	0.766
Steering Ratio (deg/deg)			1.21	

Vehicle E

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Front	Front	Front
	Tilt Table Angle (TTA) (deg)	32.1	32.8	24.9
	Tilt Table Ratio (TTR)	0.628	0.644	0.464
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Front	Front	Front
	Tilt Table Angle (TTA) (deg)	31.8	33.1	25.0
	Tilt Table Ratio (TTR)	0.619	0.651	0.467
	Average Lateral TTA (deg)	**32.0**	**32.9**	**25.0**
	Average Laleral TTR	**0.624**	**0.648**	**0.466**
Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Equal	Left
	Forward Tilt Table Angle (FTTA) (deg)	47.5	47.0	43.7
	Forward Tilt Table Ratio (FTTR)	1.092	1.074	0.955
Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Right	Left	Left
	Rearward Tilt Table Angle (RTTA) (deg)	42.4	43.6	37.9
	Rearward Tilt Table Ratio (RTTR)	0.914	0.953	0.778

Vehicle F

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5780	5781	5847
Total Vehicle Weight (lb)	526.2	739.8	761.4	924.0
Left Front Weight (lb)	149.1	166.1	190.7	211.9
Right Front Weight (lb)	122.7	172.1	179.2	198.3
Left Rear Weight (lb)	151.6	213.1	208.6	270.9
Right Rear Weight (lb)	102.8	188.5	182.9	242.9
Front Track Width (in)	32.14	32.55	32.45	32.76
Rear Track Width (in)	30.71	30.95	30.89	30.98
Average Track Width (in)	31.43	31.75	31.67	31.87
Wheelbase (in)	46.20	46.20	46.20	46.20
CG Longitudinal (in)	22.34	25.08	23.76	25.69
CG Lateral (in)	-2.23	-0.38	-0.77	-0.71
CG Height (in)		23.45	22.38	24.04
Roll Inertia - I_{XX} (ft-lb-s^2)		53	60	74
Pitch Inertia - I_{YY} (ft-lb-s^2)		74	78	114
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		52	60	93
Roll/Yaw - I_{XZ} (ft-lb-s^2)		6	4	11
SSF		0.677	0.708	0.663
KST		0.678	0.708	0.665
Steering Ratio (deg/deg)			1.29	

Vehicle F

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	26.1	26.5	22.5
	Tilt Table Ratio (TTR)	0.490	0.498	0.413
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	24.6	25.2	21.5
	Tilt Table Ratio (TTR)	0.457	0.470	0.395
	Average Lateral TTA (deg)	**25.3**	**25.8**	**22.0**
	Average Laleral TTR	**0.474**	**0.484**	**0.404**

Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Right	Left	Left
	Forward Tilt Table Angle (FTTA) (deg)	46.0	44.6	43.8
	Forward Tilt Table Ratio (FTTR)	1.036	0.987	0.958

Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Left	Left	Left
	Rearward Tilt Table Angle (RTTA) (deg)	42.0	45.4	39.5
	Rearward Tilt Table Ratio (RTTR)	0.902	1.014	0.825

Vehicle G

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5783	5784	5848
Total Vehicle Weight (lb)	694.0	909.4	928.6	1168.7
Left Front Weight (lb)	174.2	215.4	223.9	253.3
Right Front Weight (lb)	168.1	199.1	219.4	251.0
Left Rear Weight (lb)	175.9	246.6	242.5	332.9
Right Rear Weight (lb)	175.8	248.3	242.8	331.5
Front Track Width (in)	36.35	36.45	36.50	36.45
Rear Track Width (in)	35.60	36.10	36.06	36.60
Average Track Width (in)	35.98	36.28	36.28	36.53
Wheelbase (in)	50.55	50.65	50.60	50.60
CG Longitudinal (in)	25.62	27.56	26.44	28.77
CG Lateral (in)	-0.16	-0.29	-0.08	-0.06
CG Height (in)		24.07	23.34	26.13
Roll Inertia - I_{XX} (ft-lb-s^2)		79	75	109
Pitch Inertia - I_{YY} (ft-lb-s^2)		110	117	198
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		88	96	163
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	5	17
SSF		0.753	0.777	0.699
KST		0.754	0.777	0.699
Steering Ratio (deg/deg)			1.41	

Vehicle G

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	28.2	28.4	24.1
	Tilt Table Ratio (TTR)	0.535	0.540	0.446
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	28.8	28.8	24.3
	Tilt Table Ratio (TTR)	0.550	0.551	0.452
	Average Lateral TTA (deg)	**28.5**	**28.6**	**24.2**
	Average Laleral TTR	**0.542**	**0.545**	**0.449**
Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Left	Right
	Forward Tilt Table Angle (FTTA) (deg)	49.3	48.1	45.3
	Forward Tilt Table Ratio (FTTR)	1.163	1.114	1.011
Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Left	Right	Left
	Rearward Tilt Table Angle (RTTA) (deg)	43.1	44.1	38.7
	Rearward Tilt Table Ratio (RTTR)	0.935	0.969	0.802

Vehicle H

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5789	5790	
Total Vehicle Weight (lb)	395.5	608.7	654.6	
Left Front Weight (lb)	103.2	130.8	160.0	
Right Front Weight (lb)	93.4	121.8	161.2	
Left Rear Weight (lb)	99.6	178.8	163.7	
Right Rear Weight (lb)	99.3	177.3	169.7	
Front Track Width (in)	38.75	39.00	39.35	
Rear Track Width (in)	35.30	35.35	35.33	
Average Track Width (in)	37.03	37.18	37.34	
Wheelbase (in)	49.25	49.60	49.30	
CG Longitudinal (in)	24.77	29.02	25.11	
CG Lateral (in)	-0.49	-0.33	0.20	
CG Height (in)		22.08	21.45	
Roll Inertia - I_{XX} (ft-lb-s^2)		48	46	
Pitch Inertia - I_{YY} (ft-lb-s^2)		59	69	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		43	52	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		3	4	
SSF		0.842	0.870	
KST		0.849	0.871	
Steering Ratio (deg/deg)			1.41	

Vehicle H

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	
	Tilt Table Angle (TTA) (deg)	32.7	33.2	
	Tilt Table Ratio (TTR)	0.641	0.653	
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	
	Tilt Table Angle (TTA) (deg)	33.4	34.2	
	Tilt Table Ratio (TTR)	0.659	0.678	
	Average Lateral TTA (deg)	**33.0**	**33.7**	
	Average Laleral TTR	**0.650**	**0.666**	
Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Equal	
	Forward Tilt Table Angle (FTTA) (deg)	49.7	47.7	
	Forward Tilt Table Ratio (FTTR)	1.180	1.100	
Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Right	Equal	
	Rearward Tilt Table Angle (RTTA) (deg)	43.2	46.4	
	Rearward Tilt Table Ratio (RTTR)	0.940	1.049	

Vehicle I

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5786	5787	
Total Vehicle Weight (lb)	408.4	621.6	656.8	
Left Front Weight (lb)	100.9	131.8	157.7	
Right Front Weight (lb)	95.9	132.1	147.1	
Left Rear Weight (lb)	113.6	187.3	186.3	
Right Rear Weight (lb)	98.0	170.4	165.7	
Front Track Width (in)	35.85	36.40	36.50	
Rear Track Width (in)	35.55	35.63	35.63	
Average Track Width (in)	35.70	36.01	36.06	
Wheelbase (in)	47.95	48.35	48.40	
CG Longitudinal (in)	24.84	27.82	25.94	
CG Lateral (in)	-0.90	-0.48	-0.85	
CG Height (in)		23.29	22.71	
Roll Inertia - I_{XX} (ft-lb-s^2)		51	49	
Pitch Inertia - I_{YY} (ft-lb-s^2)		56	68	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		51	53	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		2	3	
SSF		0.773	0.794	
KST		0.774	0.795	
Steering Ratio (deg/deg)			1.33	

Vehicle I

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	
	Tilt Table Angle (TTA) (deg)	32.1	30.1	
	Tilt Table Ratio (TTR)	0.627	0.581	
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	
	Tilt Table Angle (TTA) (deg)	31.8	30.6	
	Tilt Table Ratio (TTR)	0.620	0.590	
	Average Lateral TTA (deg)	**32.0**	**30.3**	
	Average Laleral TTR	**0.624**	**0.585**	

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Left	
	Forward Tilt Table Angle (FTTA) (deg)	47.5	46.9	
	Forward Tilt Table Ratio (FTTR)	1.090	1.070	
Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Left	Equal	
	Rearward Tilt Table Angle (RTTA) (deg)	40.4	46.6	
	Rearward Tilt Table Ratio (RTTR)	0.851	1.058	

Vehicle J

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5792	5793	5851
Total Vehicle Weight (lb)	649.8	862.4	885.2	1135.3
Left Front Weight (lb)	172.3	202.7	216.1	255.7
Right Front Weight (lb)	160.9	195.8	208.8	248.6
Left Rear Weight (lb)	151.2	230.4	228.1	313.0
Right Rear Weight (lb)	165.4	233.5	232.2	318.0
Front Track Width (in)	36.05	36.73	36.79	36.96
Rear Track Width (in)	37.13	38.01	38.00	38.38
Average Track Width (in)	36.59	37.37	37.39	37.67
Wheelbase (in)	50.50	50.45	50.35	50.25
CG Longitudinal (in)	24.60	27.14	26.18	27.93
CG Lateral (in)	0.09	-0.08	-0.06	-0.03
CG Height (in)		23.76	23.08	25.40
Roll Inertia - I_{XX} (ft-lb-s^2)		69	68	87
Pitch Inertia - I_{YY} (ft-lb-s^2)		98	103	176
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		69	89	154
Roll/Yaw - I_{XZ} (ft-lb-s^2)		8	8	14
SSF		0.786	0.810	0.742
KST		0.785	0.810	0.740
Steering Ratio (deg/deg)			1.42	

Vehicle J

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	30.4	30.6	26.8
	Tilt Table Ratio (TTR)	0.586	0.592	0.505
Lateral Direction: Left Tilt	**Tilt Table: First Wheel Lift**	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	30.2	30.6	26.4
	Tilt Table Ratio (TTR)	0.583	0.591	0.496
	Average Lateral TTA (deg)	**30.3**	**30.6**	**26.6**
	Average Laleral TTR	**0.585**	**0.591**	**0.500**

Longitudinal Direction: Front Tilt	**Tilt Table: First Wheel Lift**	Left	Left	Right
	Forward Tilt Table Angle (FTTA) (deg)	48.1	47.2	45.0
	Forward Tilt Table Ratio (FTTR)	1.115	1.079	0.999

Longitudinal Direction: Rear Tilt	**Tilt Table: First Wheel Lift**	Right	Left	Left
	Rearward Tilt Table Angle (RTTA) (deg)	43.8	45.6	39.5
	Rearward Tilt Table Ratio (RTTR)	0.959	1.021	0.824

Vehicle K

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5795	5796	5852
Total Vehicle Weight (lb)	832.0	1044.8	1070.7	1412.1
Left Front Weight (lb)	206.7	239.9	241.8	283.8
Right Front Weight (lb)	192.0	220.6	224.7	268.3
Left Rear Weight (lb)	227.2	295.8	303.9	435.4
Right Rear Weight (lb)	206.1	288.5	300.3	424.6
Front Track Width (in)	39.96	40.83	40.83	41.30
Rear Track Width (in)	38.20	39.24	39.16	40.13
Average Track Width (in)	39.08	40.03	39.99	40.71
Wheelbase (in)	53.15	53.15	53.20	53.20
CG Longitudinal (in)	27.68	29.72	30.02	32.40
CG Lateral (in)	-0.84	-0.51	-0.39	-0.38
CG Height (in)		23.44	22.92	25.51
Roll Inertia - I_{XX} (ft-lb-s^2)		73	79	110
Pitch Inertia - I_{YY} (ft-lb-s^2)		130	138	234
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		116	126	208
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	5	17
SSF		0.854	0.873	0.798
KST		0.856	0.875	0.800
Steering Ratio (deg/deg)			1.43	

Vehicle K

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	Tilt Table: First Wheel Lift	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	33.7	33.0	28.3
	Tilt Table Ratio (TTR)	0.668	0.649	0.539
Lateral Direction: Left Tilt	Tilt Table: First Wheel Lift	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	33.9	34.0	29.8
	Tilt Table Ratio (TTR)	0.672	0.675	0.573
	Average Lateral TTA (deg)	**33.8**	**33.5**	**29.1**
	Average Laleral TTR	**0.670**	**0.662**	**0.556**

Longitudinal Direction: Front Tilt	Tilt Table: First Wheel Lift	Equal	Right	Left
	Forward Tilt Table Angle (FTTA) (deg)	53.8	51.3	49.5
	Forward Tilt Table Ratio (FTTR)	1.365	1.247	1.170

Longitudinal Direction: Rear Tilt	Tilt Table: First Wheel Lift	Left	Left	Left
	Rearward Tilt Table Angle (RTTA) (deg)	42.7	46.2	40.2
	Rearward Tilt Table Ratio (RTTR)	0.924	1.044	0.844

Vehicle L

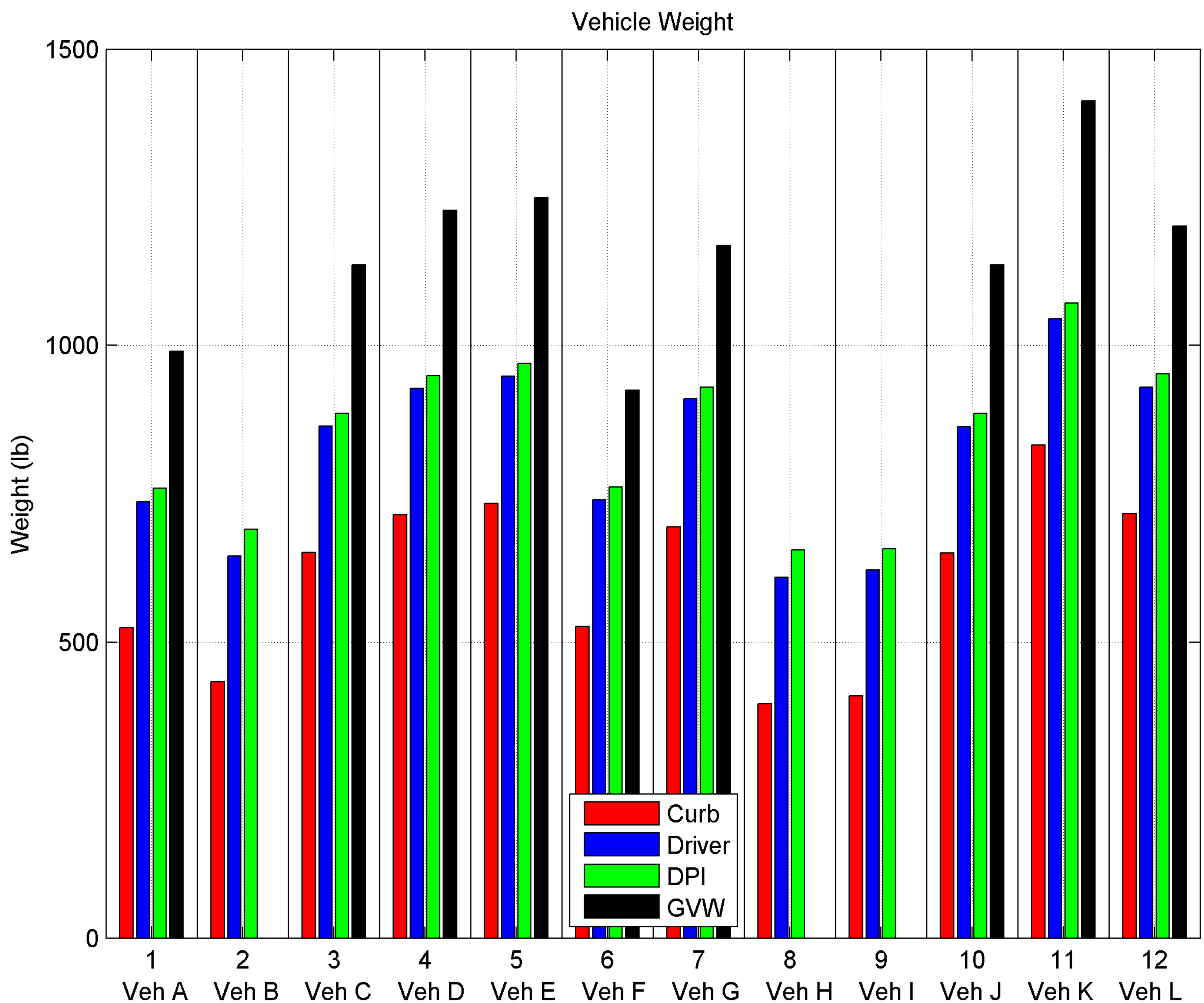
	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
VIMF Test Number		5798	5799	5853
Total Vehicle Weight (lb)	716.4	929.1	951.1	1201.3
Left Front Weight (lb)	185.8	216.9	235.3	261.4
Right Front Weight (lb)	159.6	202.4	217.1	250.3
Left Rear Weight (lb)	189.5	253.1	246.8	342.1
Right Rear Weight (lb)	181.5	256.7	251.9	347.5
Front Track Width (in)	39.59	39.76	39.80	39.40
Rear Track Width (in)	37.00	37.50	37.50	36.90
Average Track Width (in)	38.29	38.63	38.65	38.15
Wheelbase (in)	50.50	50.60	50.60	50.45
CG Longitudinal (in)	26.15	27.76	26.53	28.96
CG Lateral (in)	-0.93	-0.24	-0.28	-0.10
CG Height (in)		22.96	22.53	25.02
Roll Inertia - I_{XX} (ft-lb-s^2)		78	84	132
Pitch Inertia - I_{YY} (ft-lb-s^2)		115	120	185
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		98	101	157
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	7	18
SSF		0.841	0.858	0.762
KST		0.844	0.859	0.766
Steering Ratio (deg/deg)			1.60	

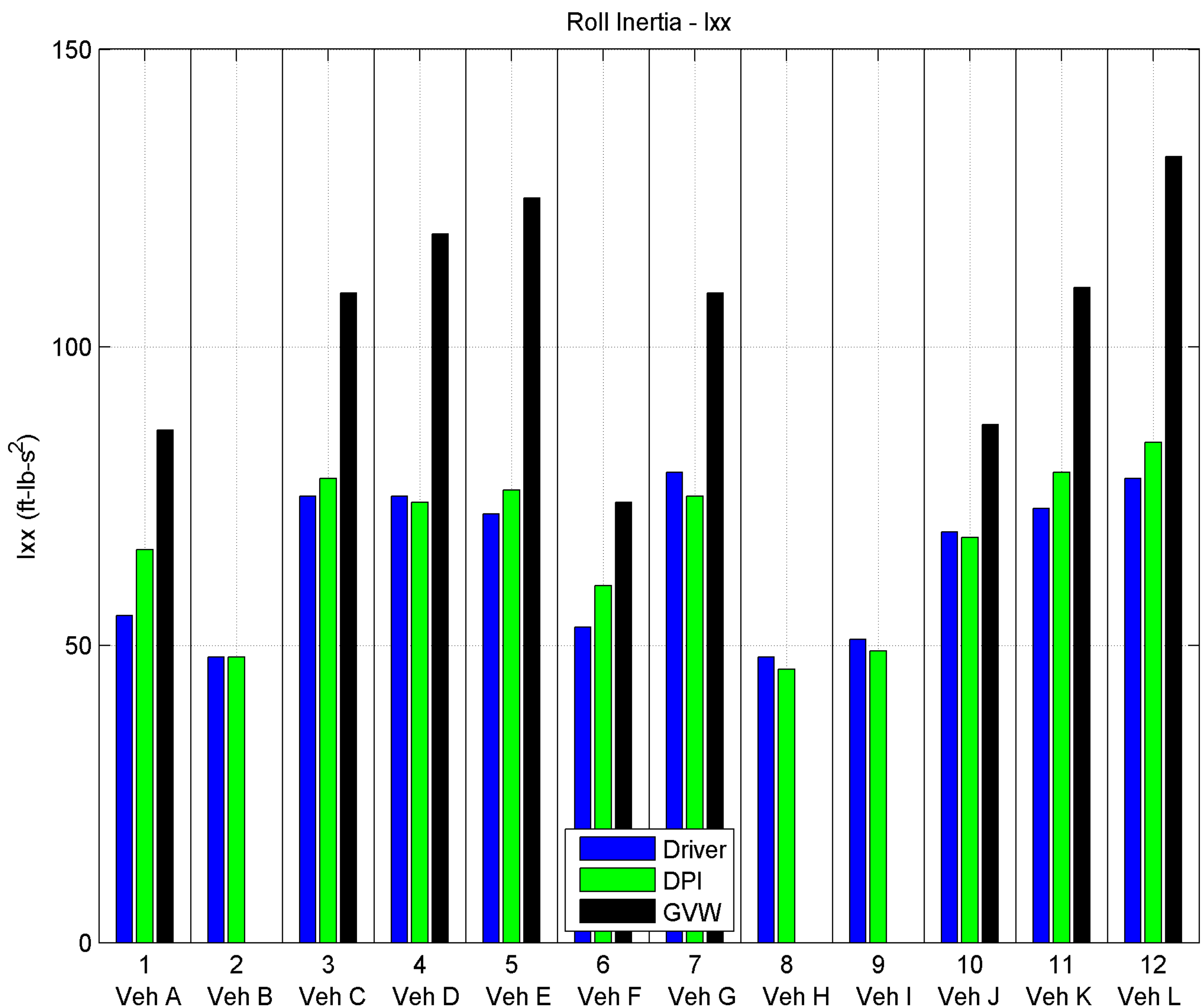
Vehicle L

		Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)
Lateral Direction: Right Tilt	Tilt Table: First Wheel Lift	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	32.5	33.2	28.5
	Tilt Table Ratio (TTR)	0.636	0.653	0.543
Lateral Direction: Left Tilt	Tilt Table: First Wheel Lift	Rear	Rear	Rear
	Tilt Table Angle (TTA) (deg)	33.6	33.5	29.6
	Tilt Table Ratio (TTR)	0.663	0.661	0.569
	Average Lateral TTA (deg)	**33.0**	**33.3**	**29.1**
	Average Laleral TTR	**0.650**	**0.657**	**0.556**

Longitudinal Direction: Front Tilt	Tilt Table: First Wheel Lift	Left	Left	Left
	Forward Tilt Table Angle (FTTA) (deg)	50.5	50.0	47.5
	Forward Tilt Table Ratio (FTTR)	1.214	1.192	1.092

Longitudinal Direction: Rear Tilt	Tilt Table: First Wheel Lift	Left	Left	Left
	Rearward Tilt Table Angle (RTTA) (deg)	43.5	45.7	41.4
	Rearward Tilt Table Ratio (RTTR)	0.947	1.024	0.883


Vehicle Weight
1500
1000
500
0
Weight (lb)
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Curb
Driver
DPI
GVW



Roll Inertia - Ixx
Ixx (ft-lb-s^2)
150
100
50
0
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
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Veh H
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Veh I
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Veh J
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Veh K
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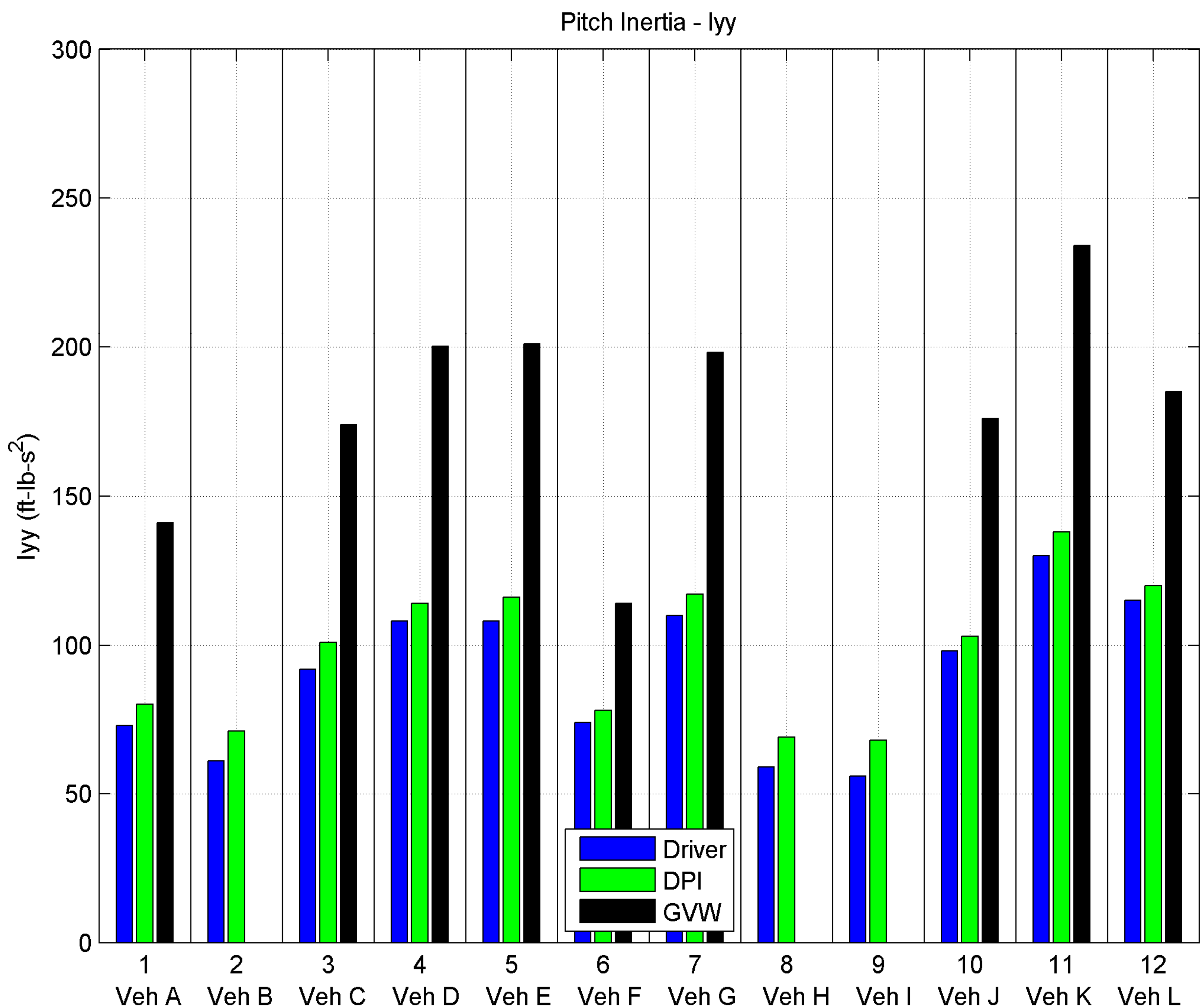
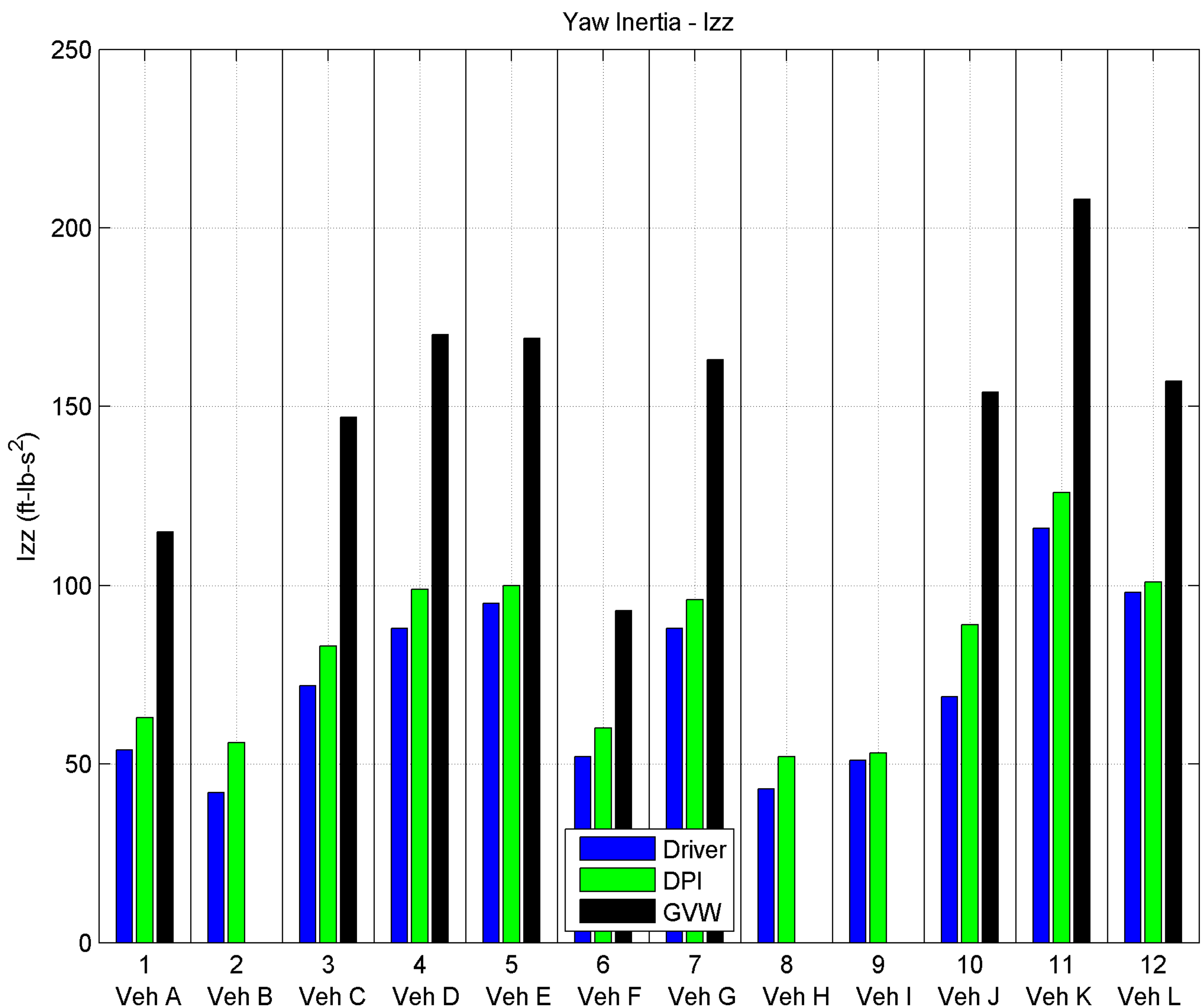
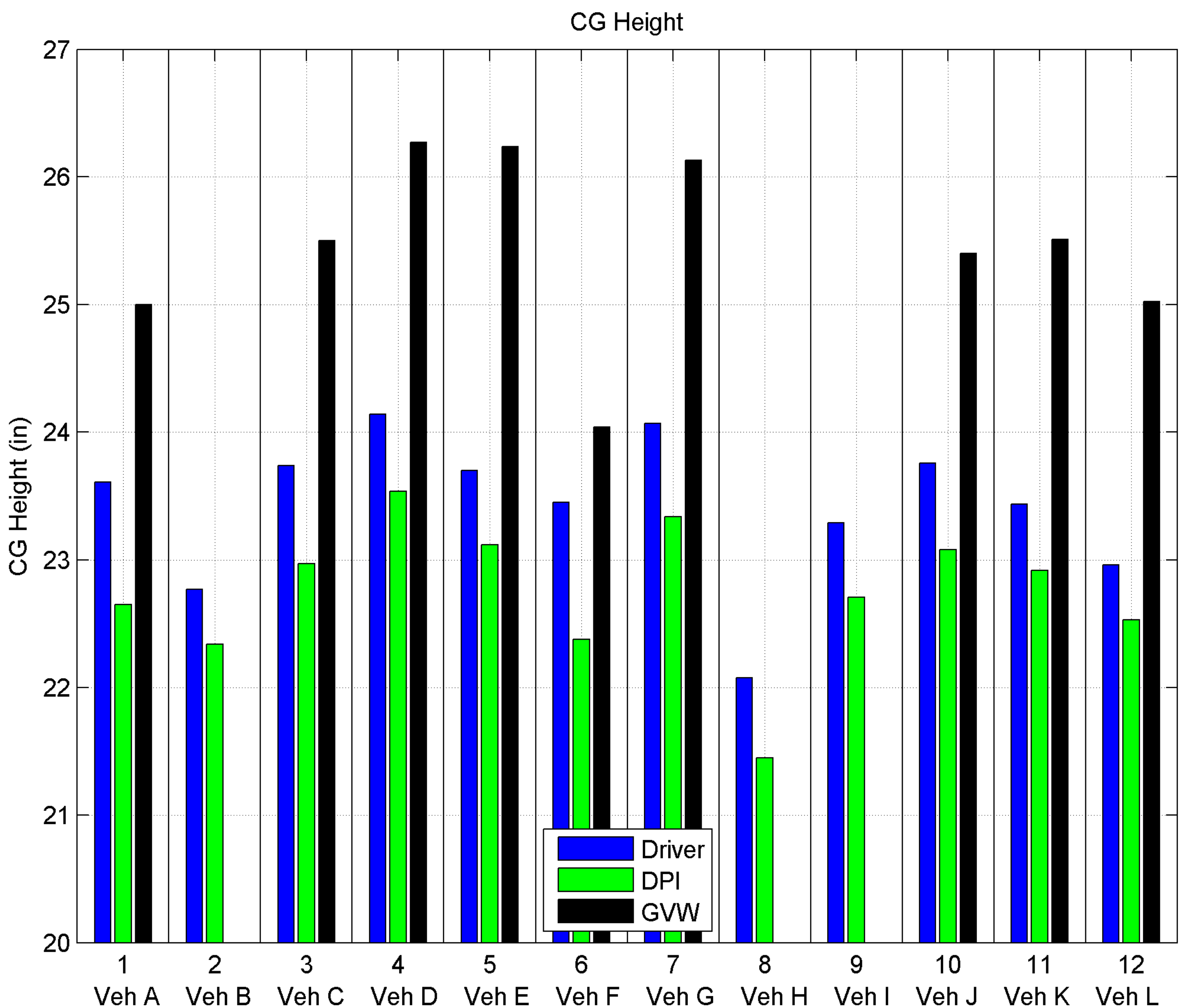
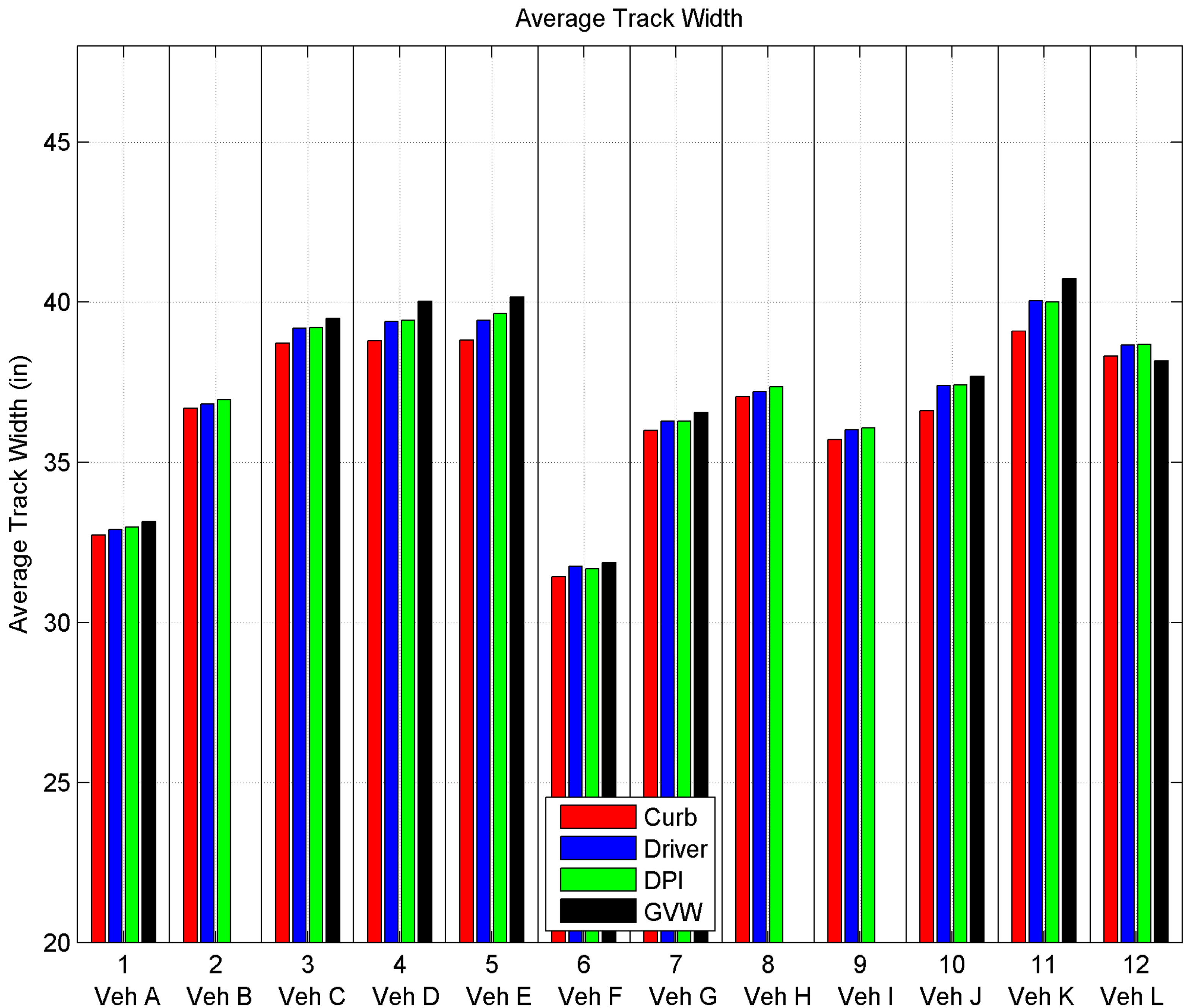
Veh L
Driver
DPI
GVW

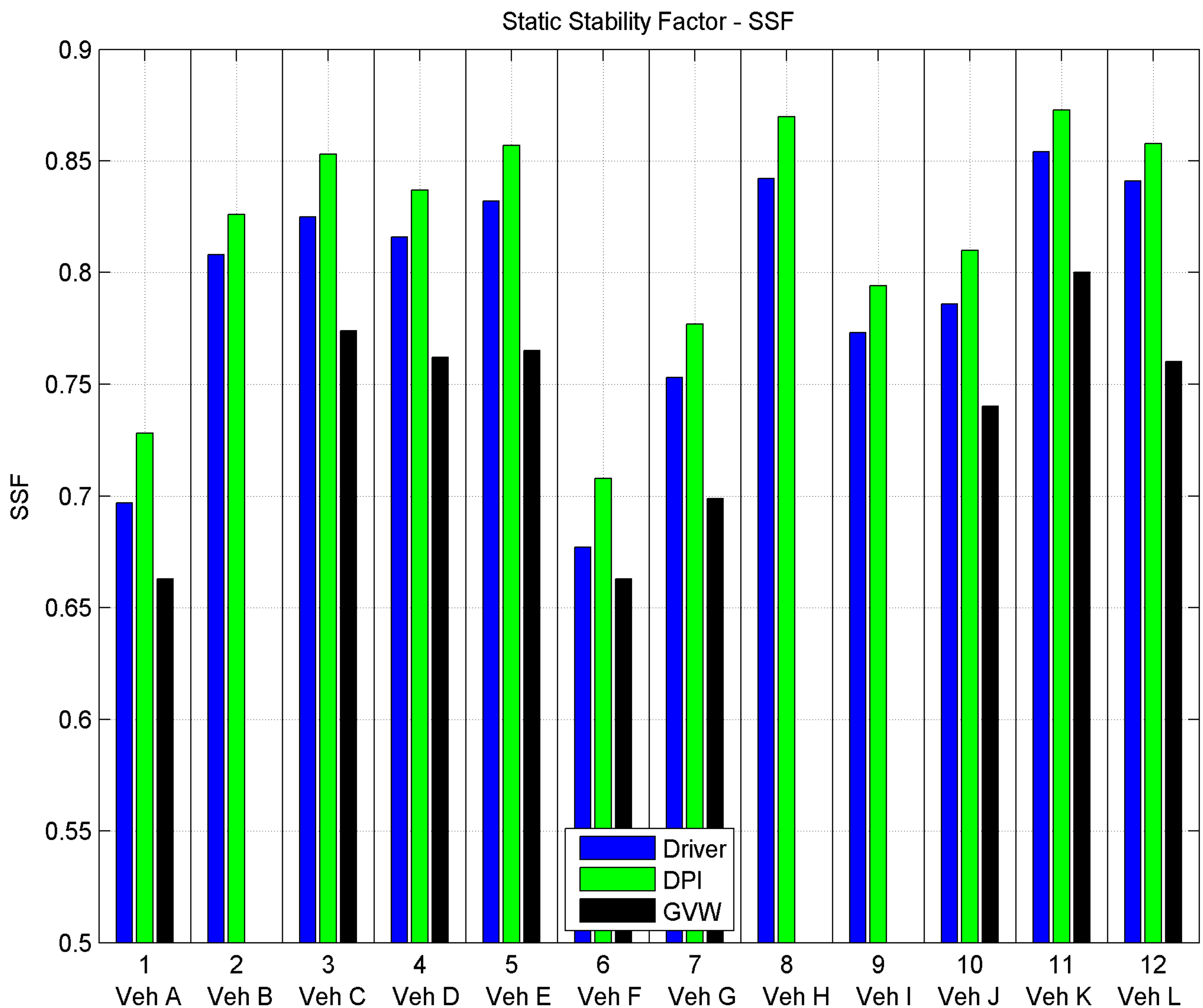

Pitch Inertia - Iyy
Iyy (ft-lb-s^2)
300
250
200
150
100
50
0
Driver
DPI
GVW
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

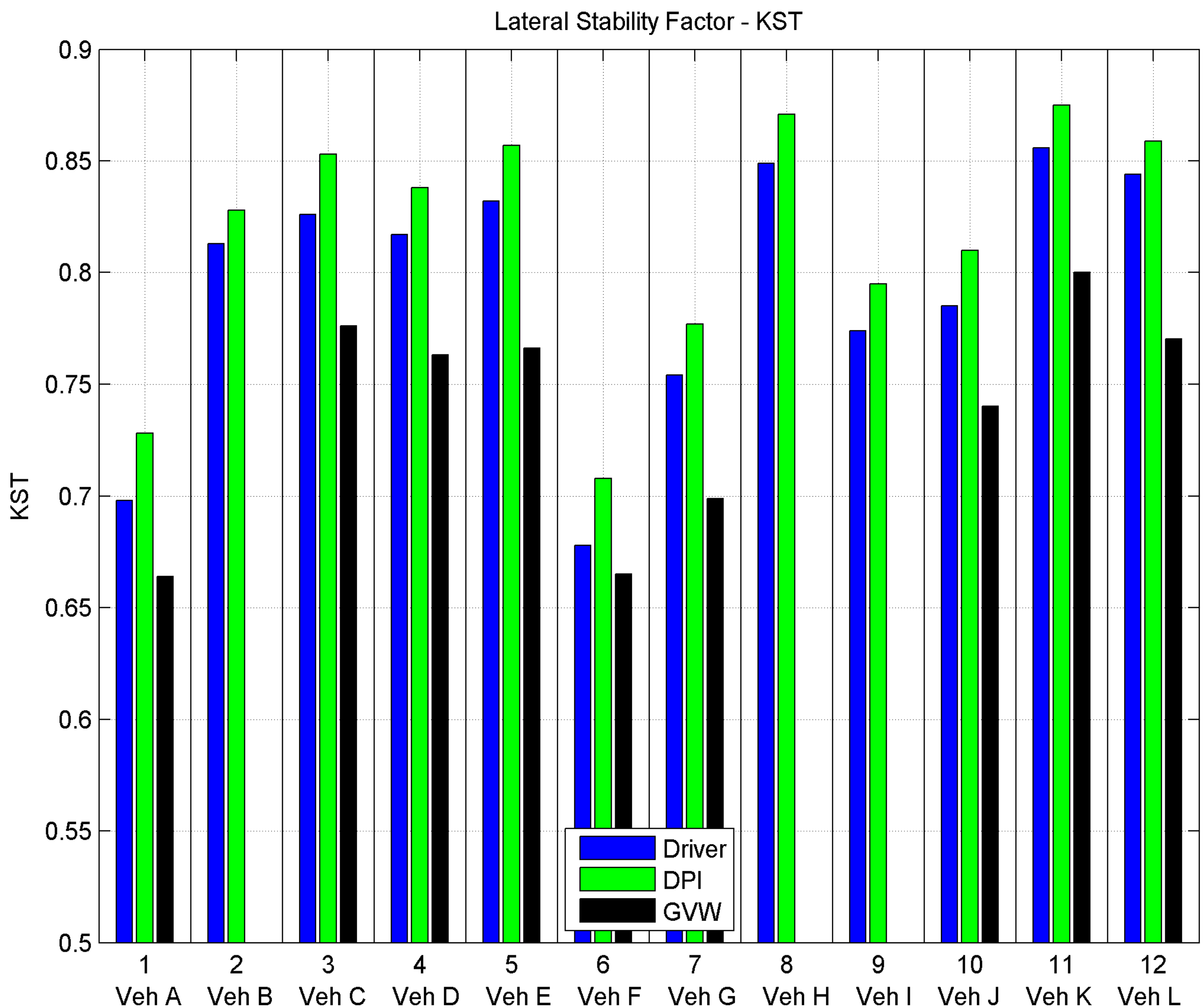

Yaw Inertia - Izz
Izz (ft-lb-s^2)
250
200
150
100
50
0
Driver
DPI
GVW
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

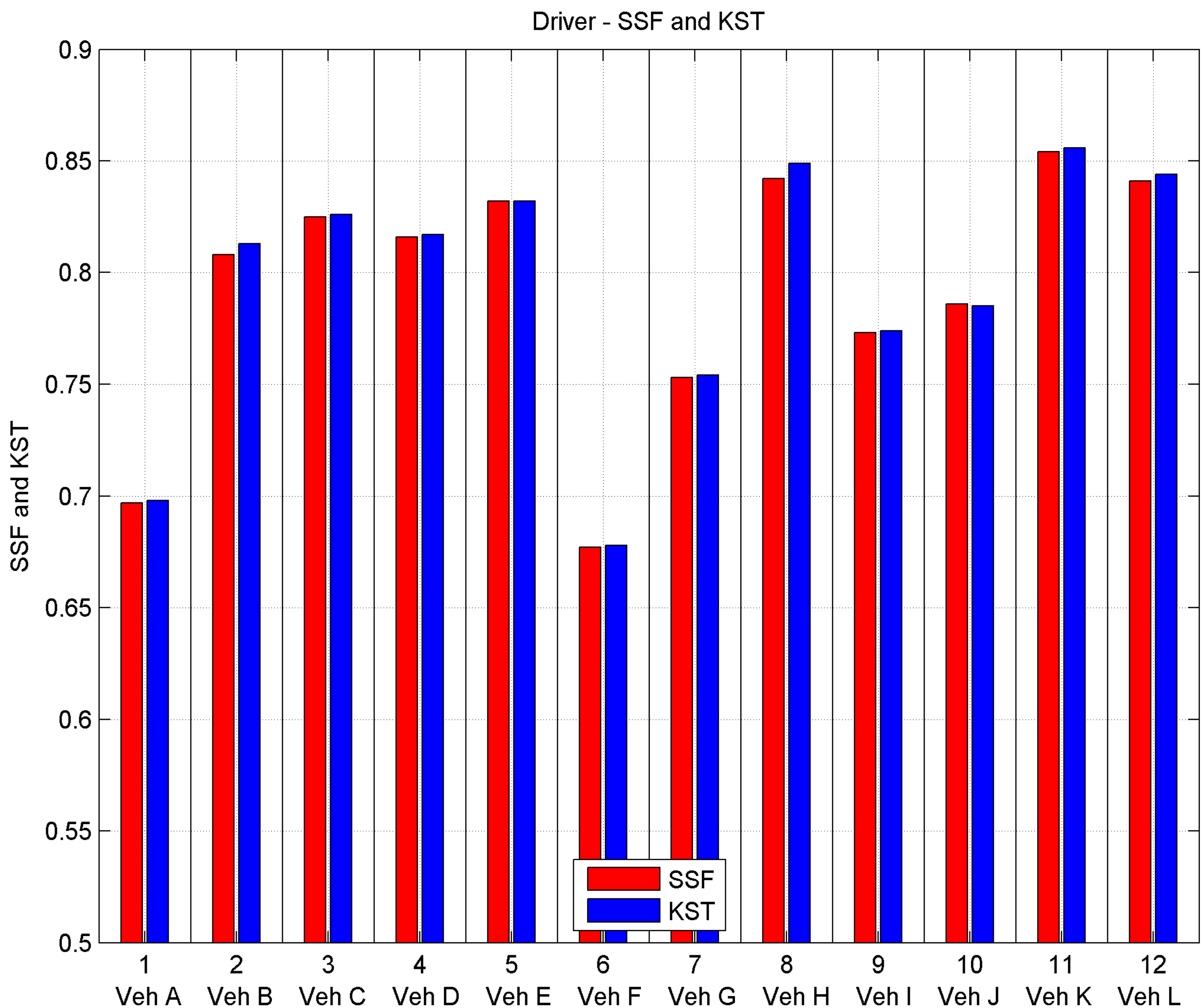

CG Height
CG Height (in)
27
26
25
24
23
22
21
20
1 Veh A
2 Veh B
3 Veh C
4 Veh D
5 Veh E
6 Veh F
7 Veh G
8 Veh H
9 Veh I
10 Veh J
11 Veh K
12 Veh L
Driver
DPI
GVW

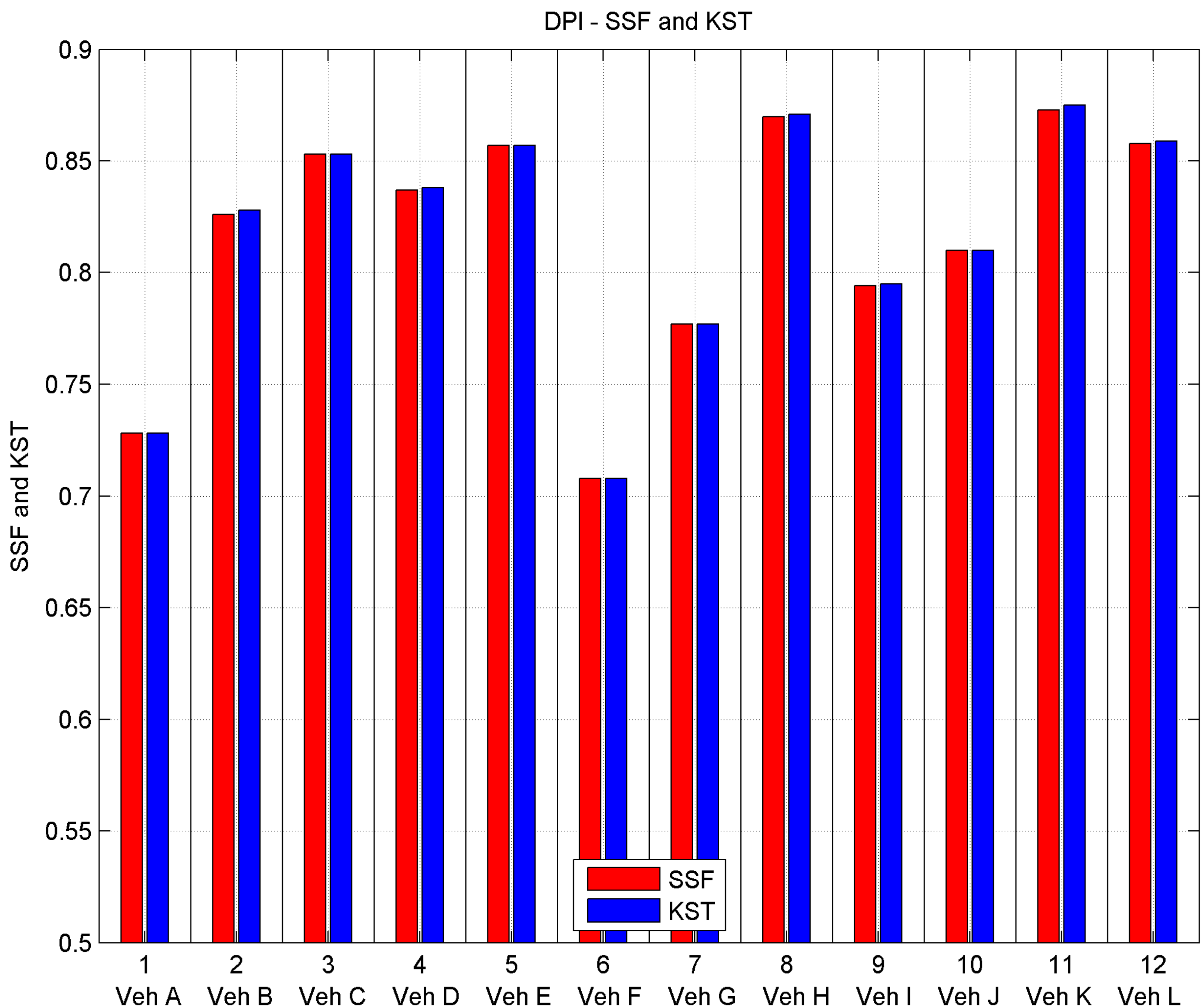


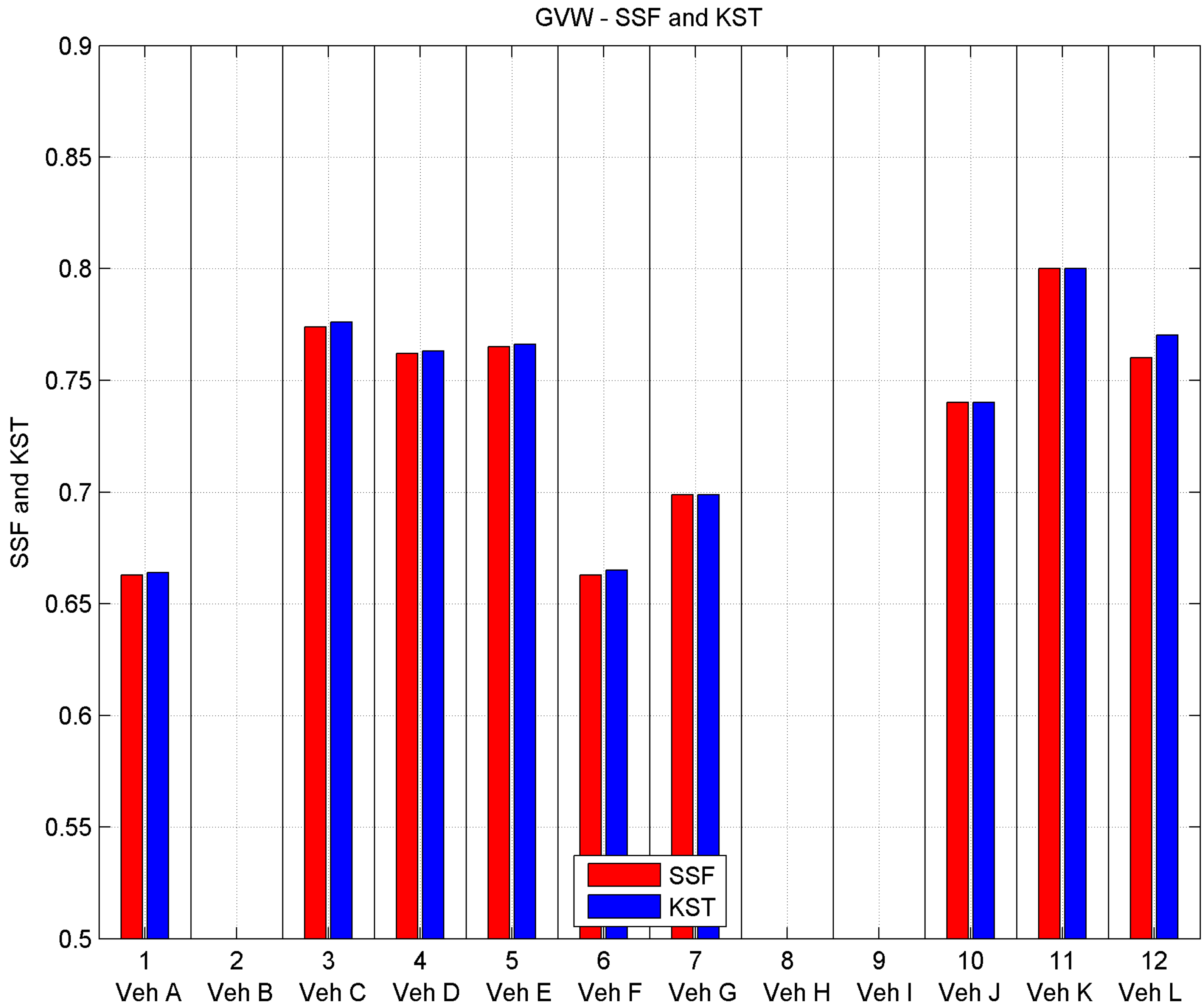
Average Track Width
Average Track Width (in)
45
40
35
30
25
20
1
2
3
4
5
6
7
8
9
10
11
12
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I
Veh J
Veh K
Veh L
Curb
Driver
DPI
GVW


Static Stability Factor - SSF
SSF
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Driver
DPI
GVW
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

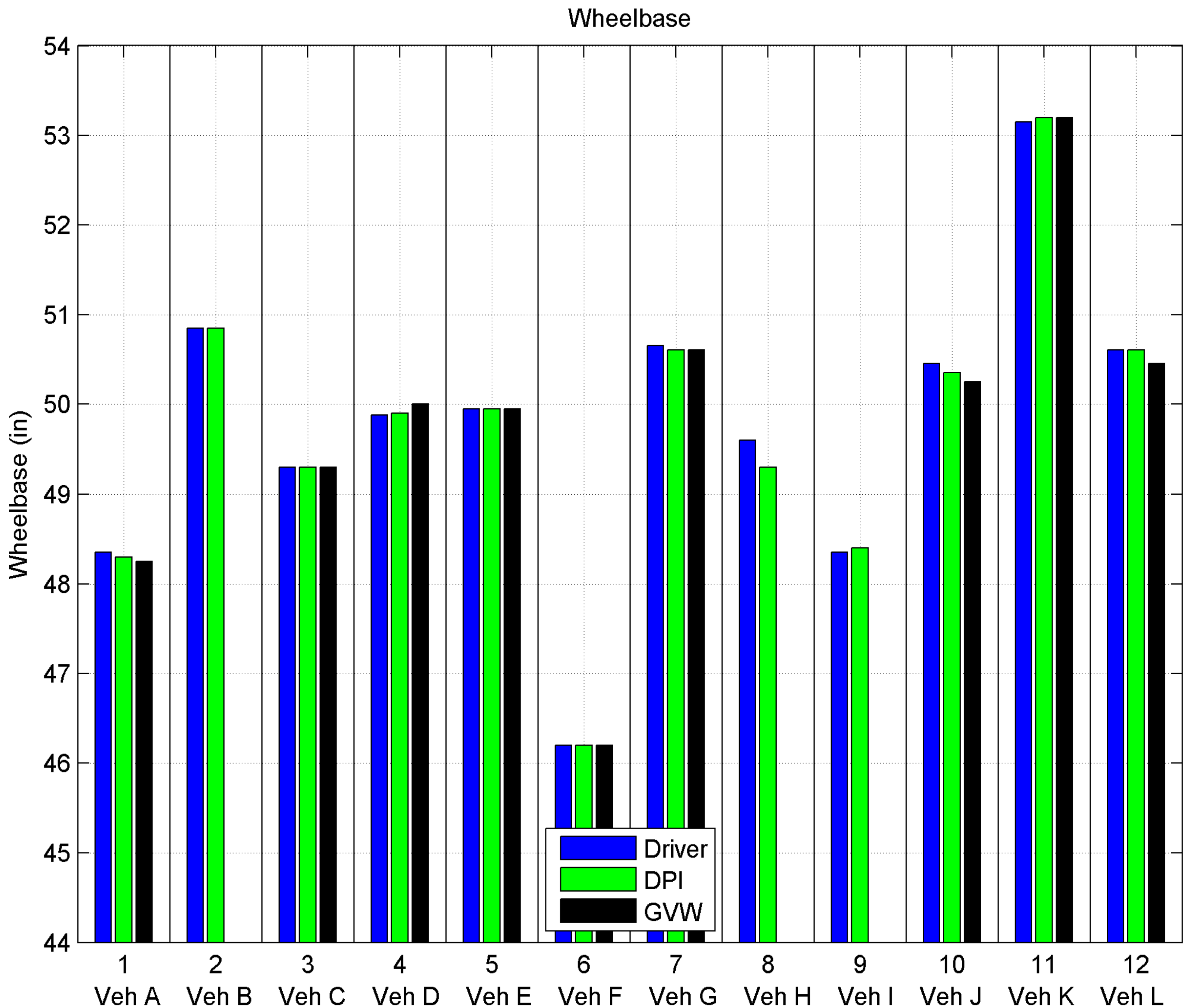

Lateral Stability Factor - KST
KST
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Driver
DPI
GVW
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

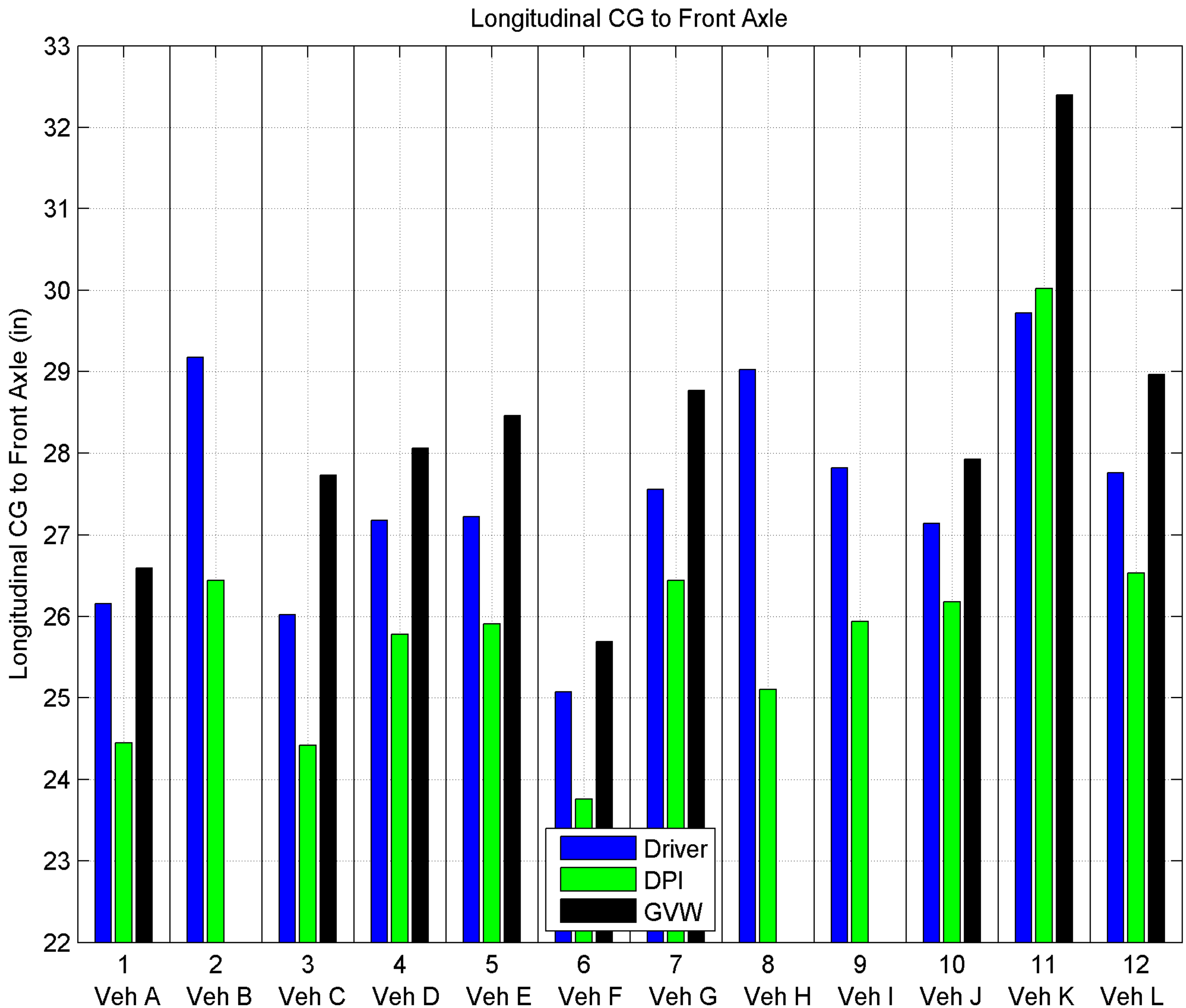

Driver - SSF and KST
SSF and KST
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
SSF
KST
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

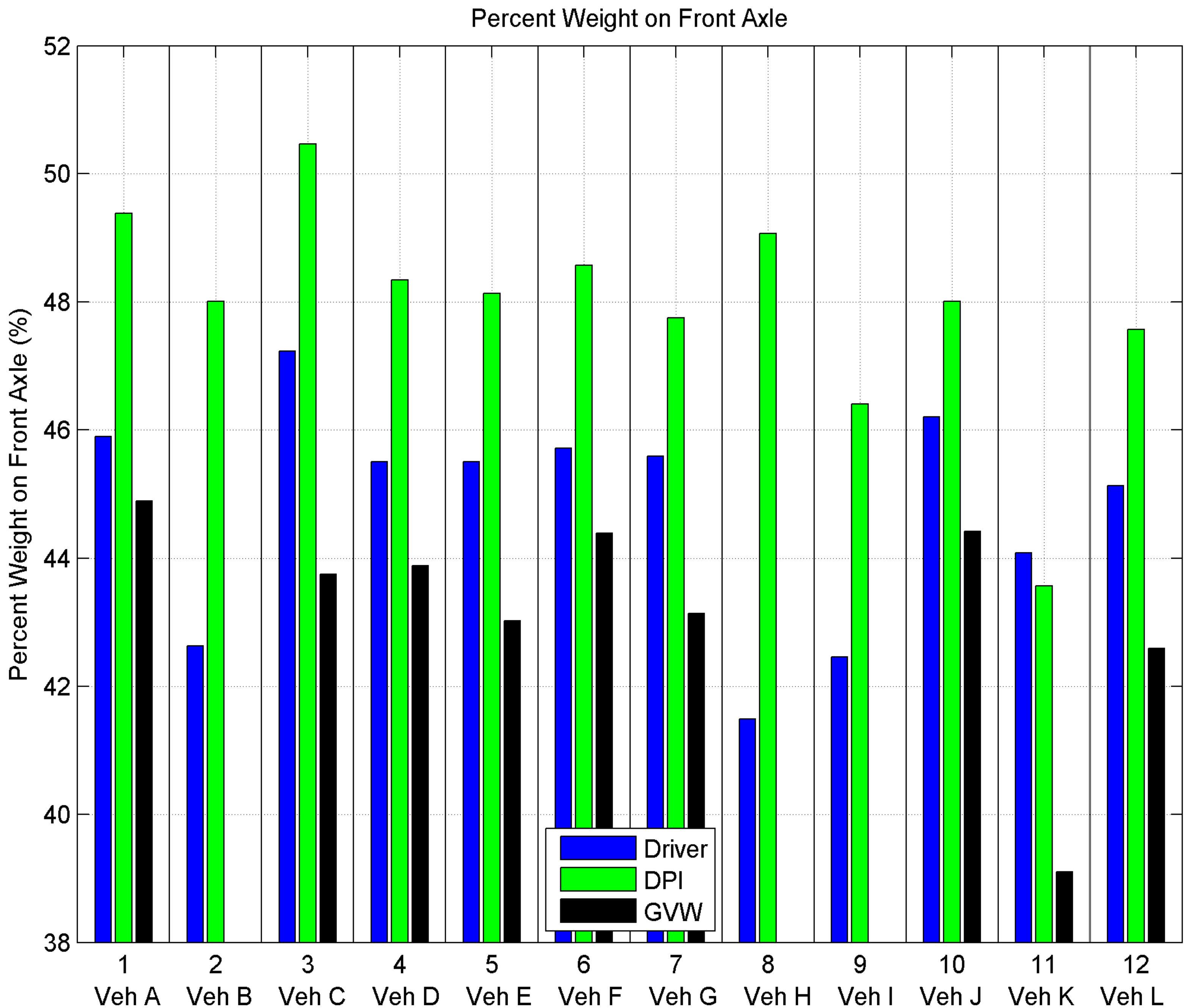

DPI - SSF and KST
SSF and KST
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
SSF
KST

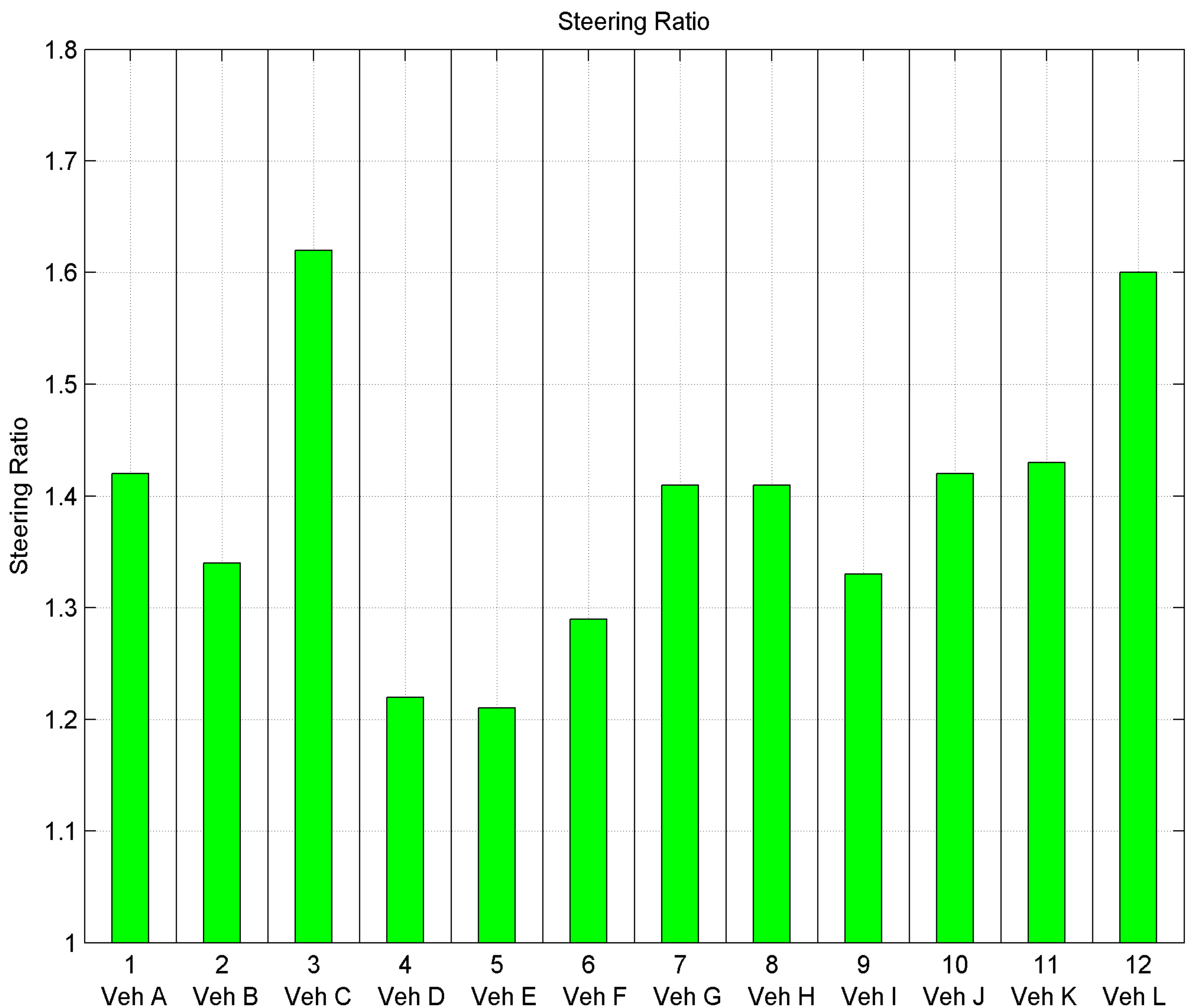


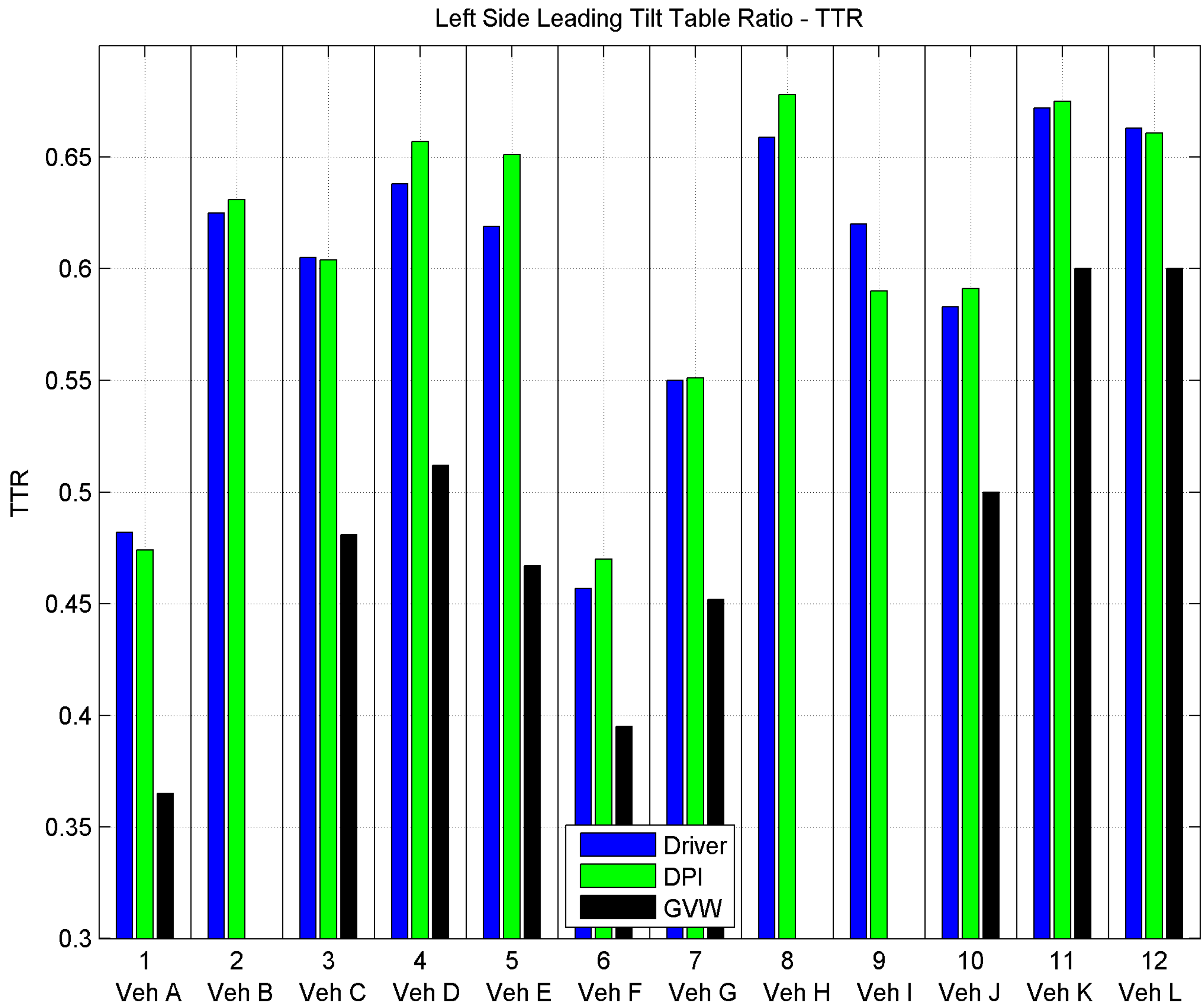
GVW - SSF and KST
SSF and KST
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
SSF
KST
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L


Wheelbase
Wheelbase (in)
54
53
52
51
50
49
48
47
46
45
44
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Driver
DPI
GVW

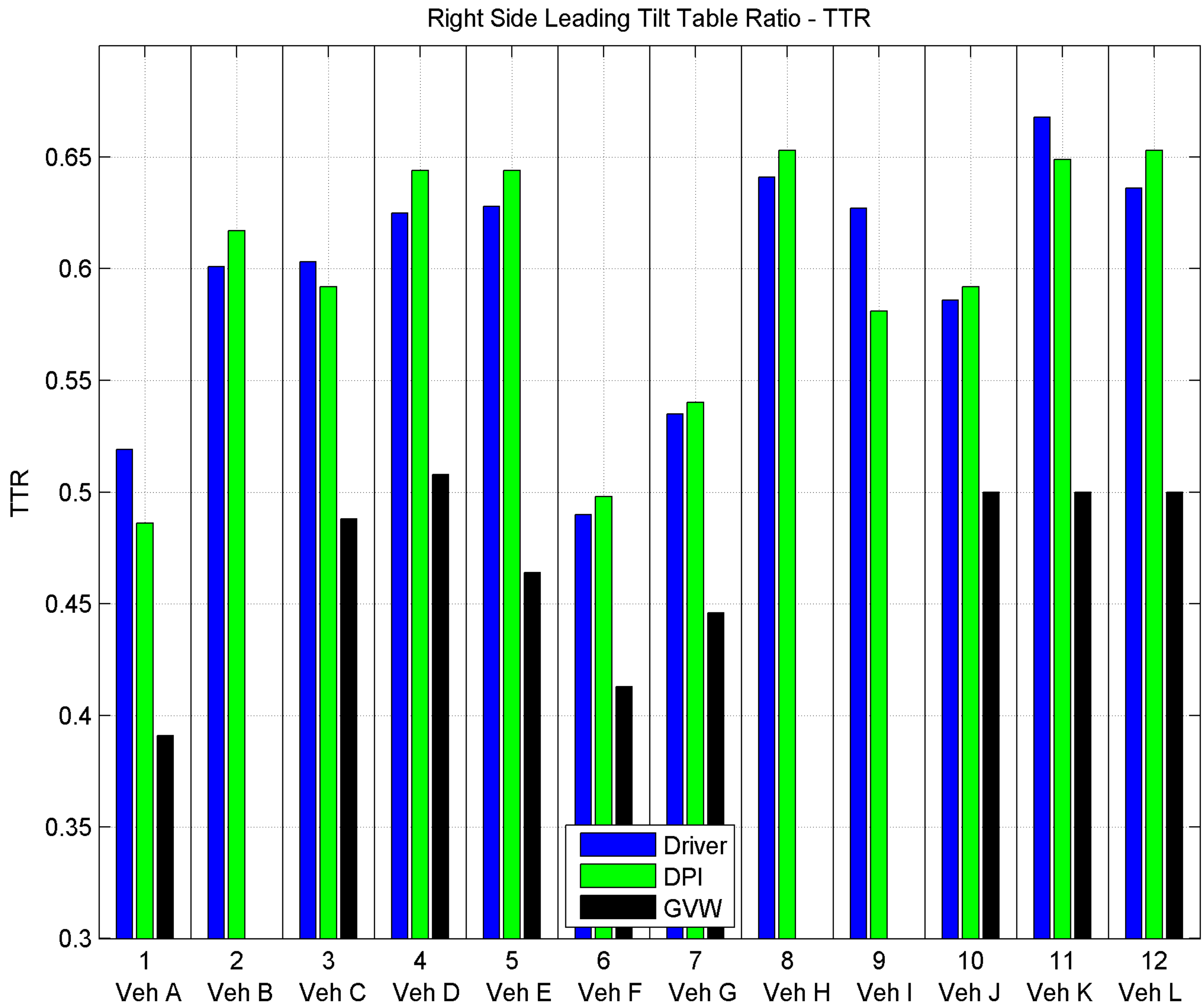

Longitudinal CG to Front Axle
Longitudinal CG to Front Axle (in)
33
32
31
30
29
28
27
26
25
24
23
22
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Driver
DPI
GVW

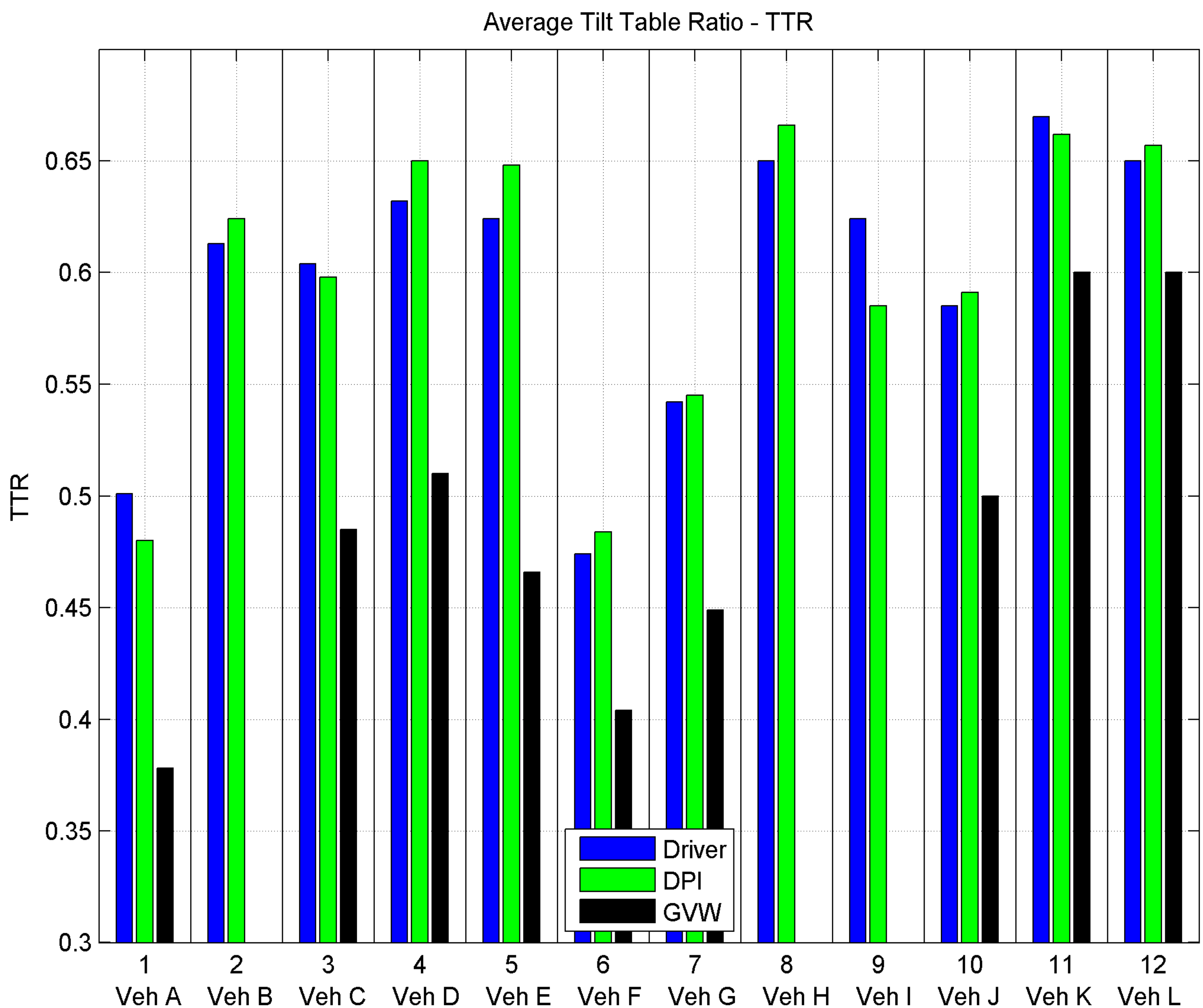

Percent Weight on Front Axle
Percent Weight on Front Axle (%)
52
50
48
46
44
42
40
38
Driver
DPI
GVW
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

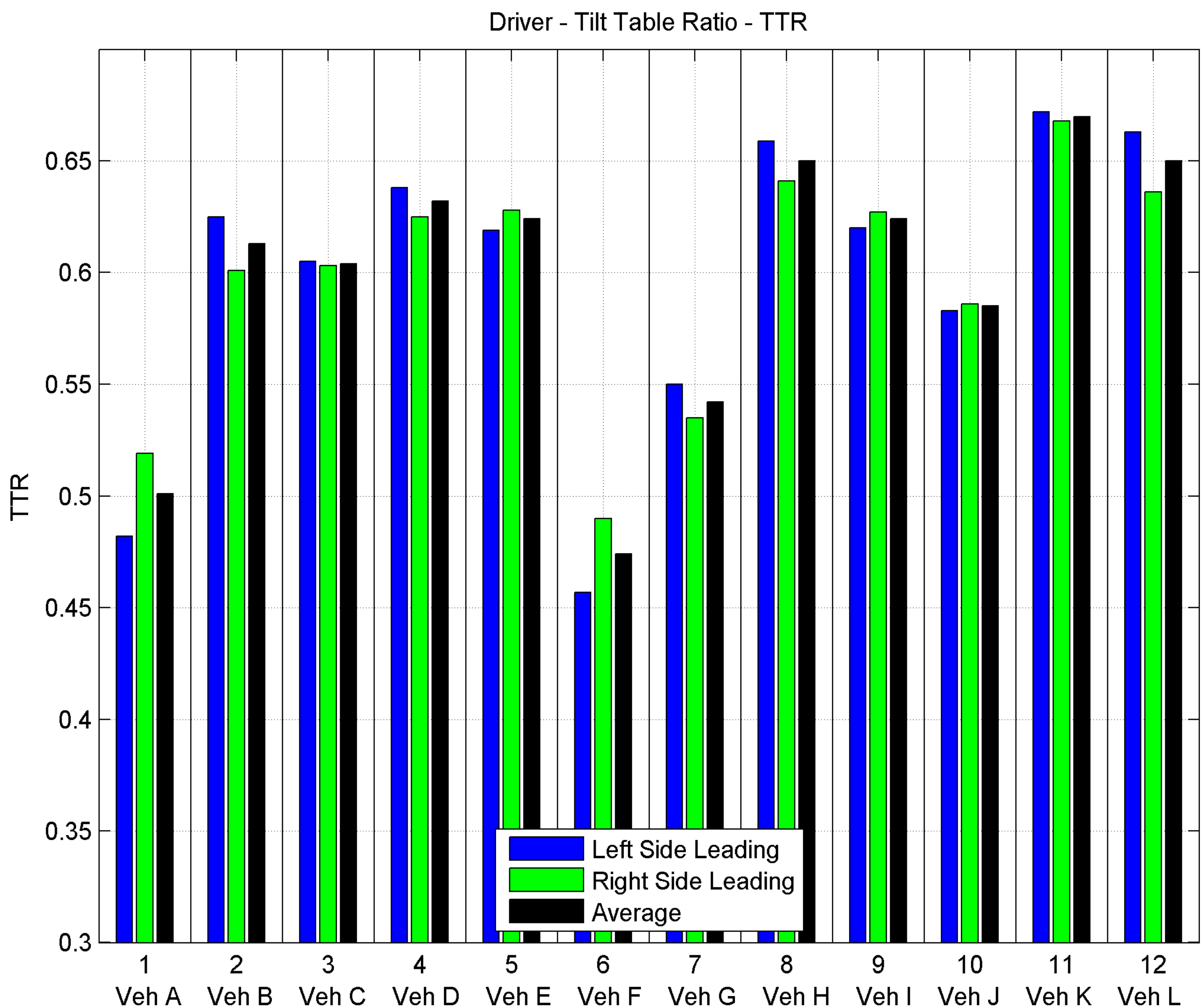

Steering Ratio
Steering Ratio
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
1 Veh A
2 Veh B
3 Veh C
4 Veh D
5 Veh E
6 Veh F
7 Veh G
8 Veh H
9 Veh I
10 Veh J
11 Veh K
12 Veh L

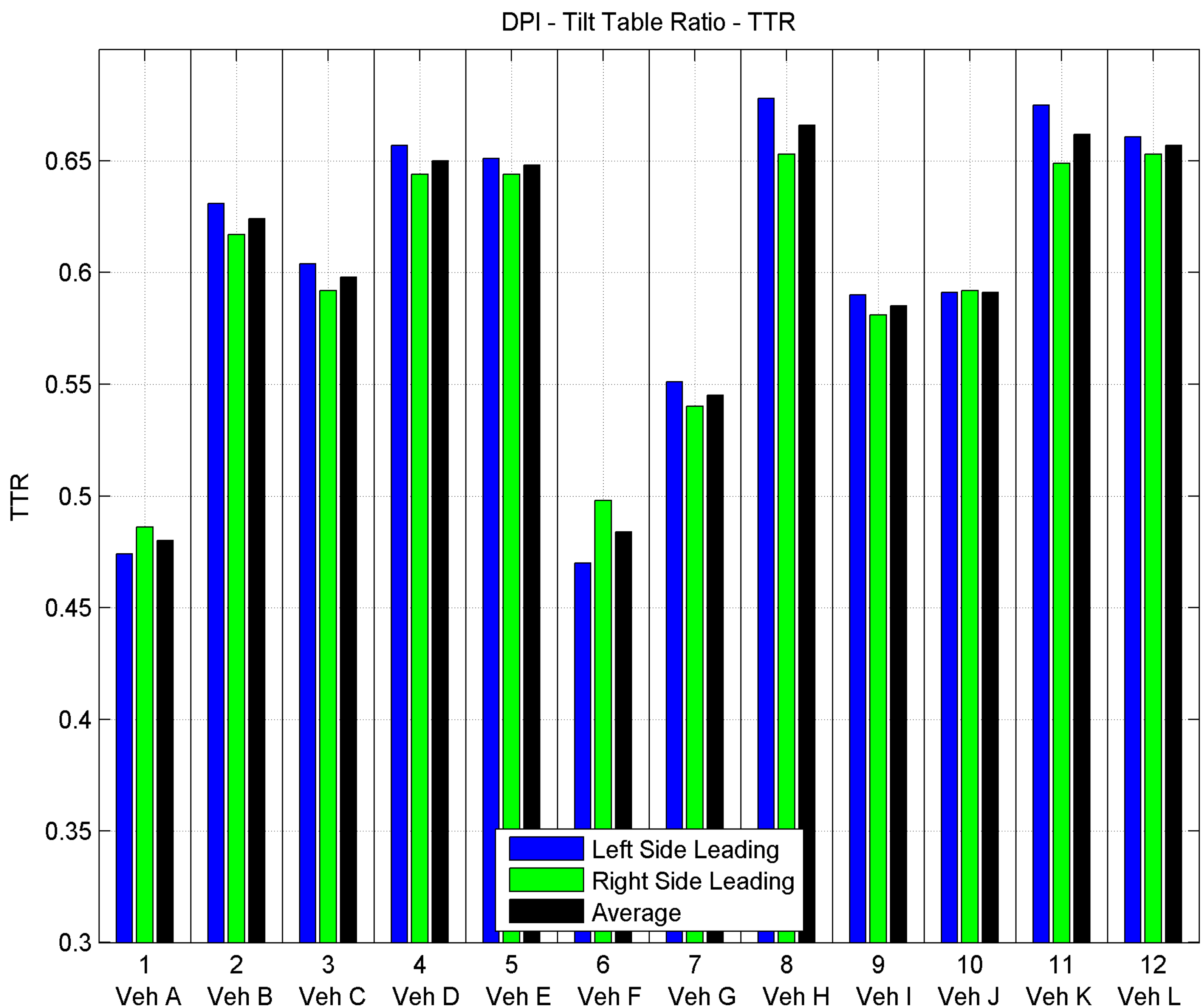


Left Side Leading Tilt Table Ratio - TTR
TTR
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
1 Veh A
2 Veh B
3 Veh C
4 Veh D
5 Veh E
6 Veh F
7 Veh G
8 Veh H
9 Veh I
10 Veh J
11 Veh K
12 Veh L
Driver
DPI
GVW

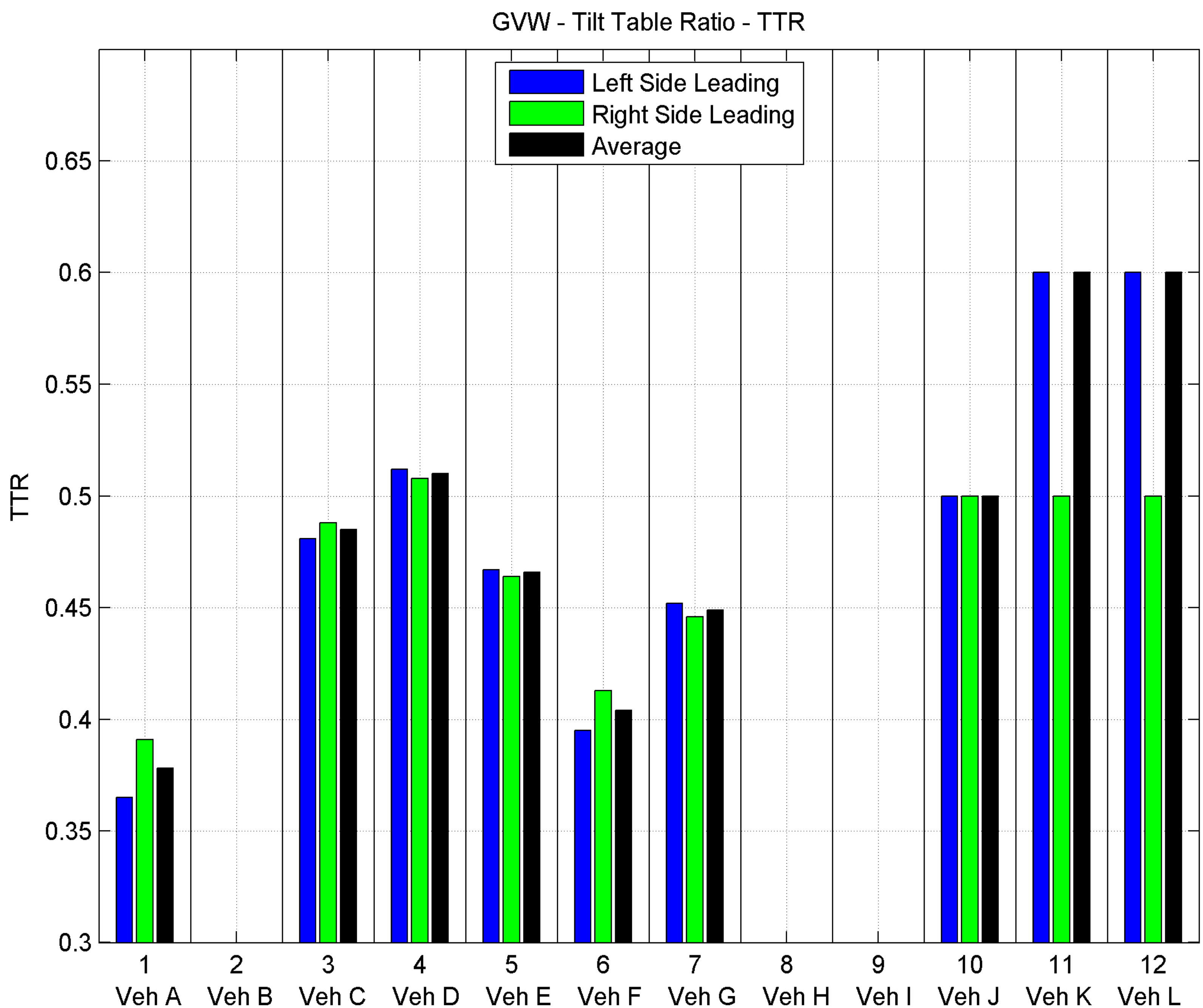

Right Side Leading Tilt Table Ratio - TTR
TTR
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Driver
DPI
GVW

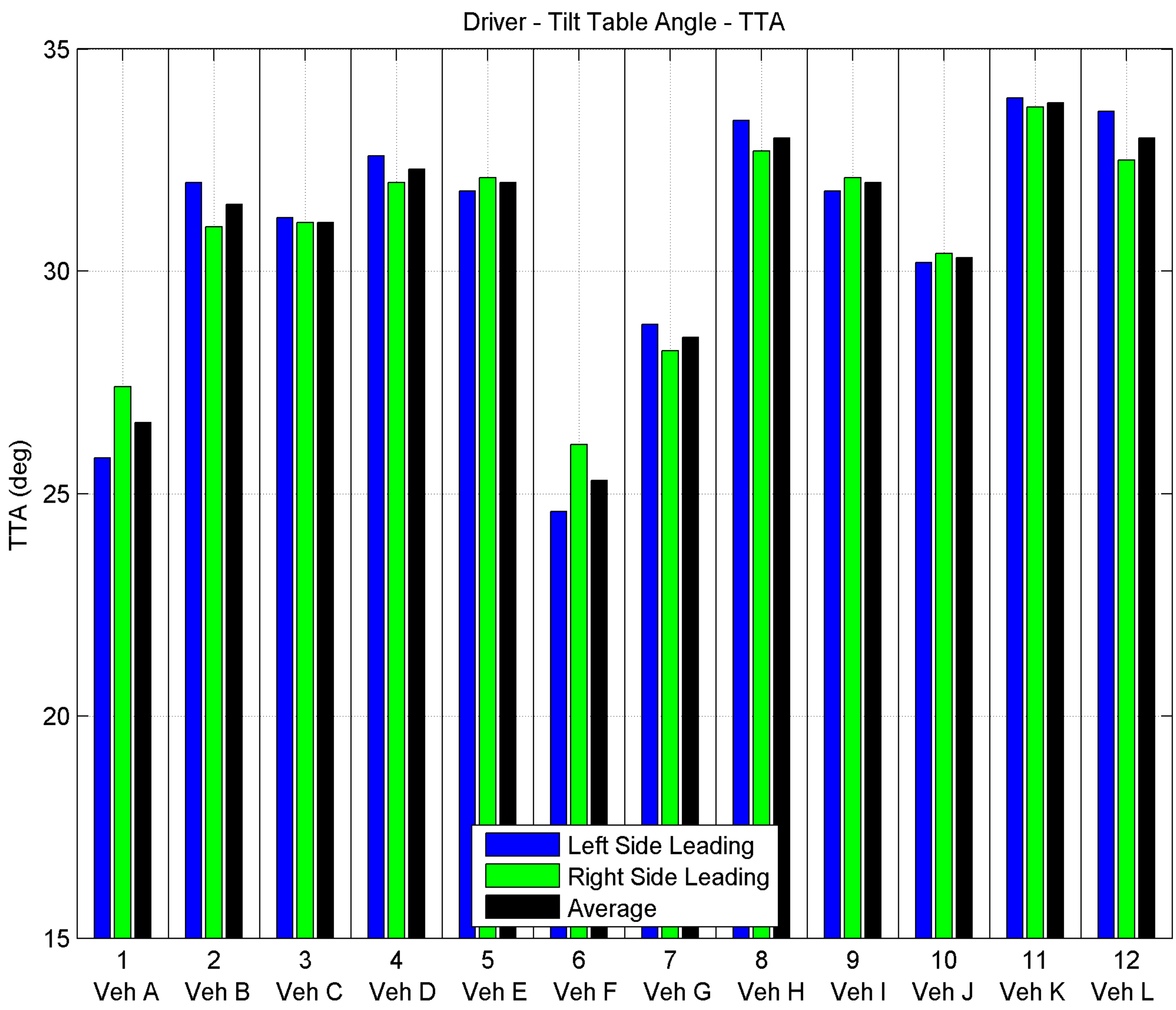

Average Tilt Table Ratio - TTR
TTR
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
1 Veh A
2 Veh B
3 Veh C
4 Veh D
5 Veh E
6 Veh F
7 Veh G
8 Veh H
9 Veh I
10 Veh J
11 Veh K
12 Veh L
Driver
DPI
GVW

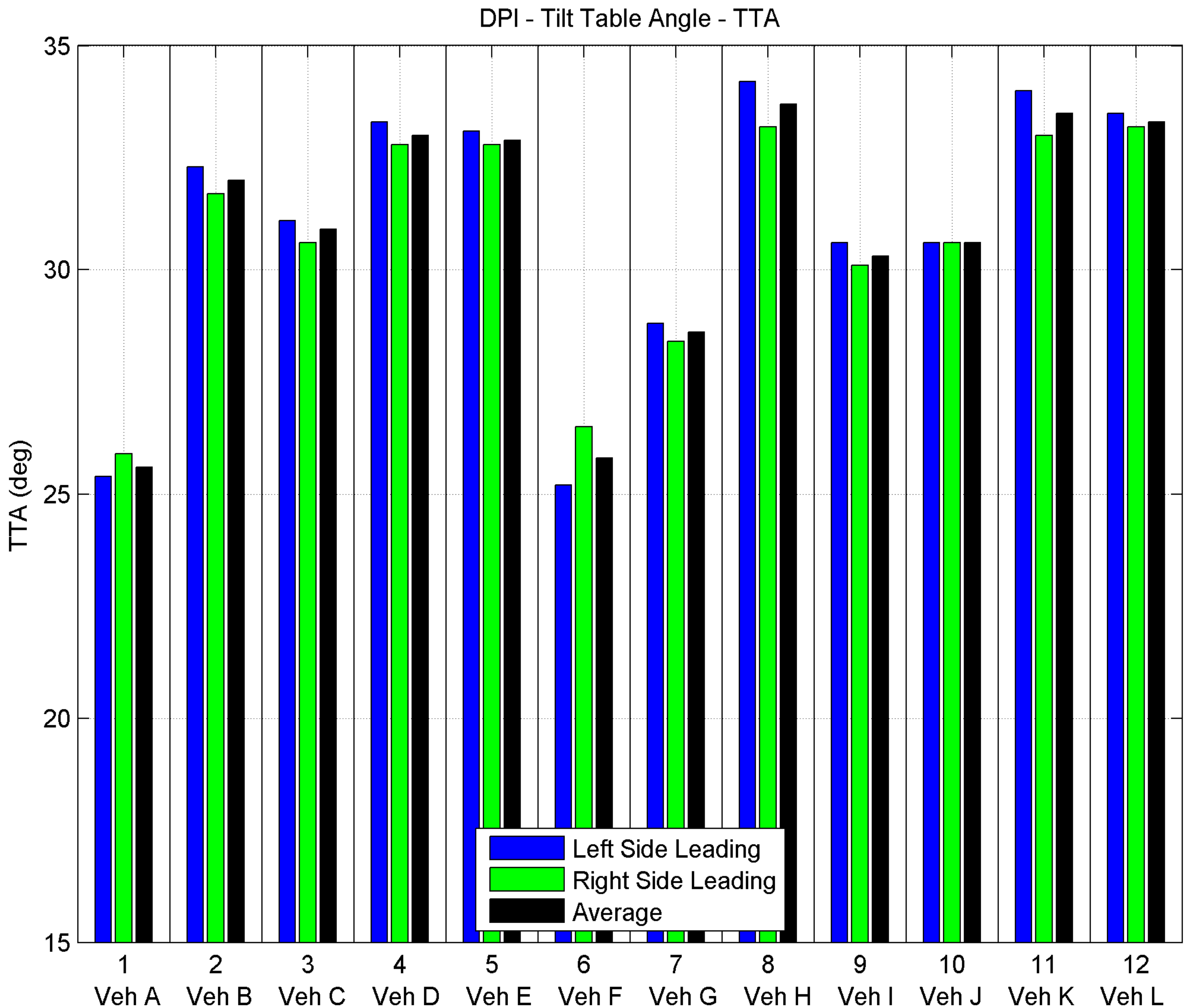

Driver - Tilt Table Ratio - TTR
TTR
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Left Side Leading
Right Side Leading
Average

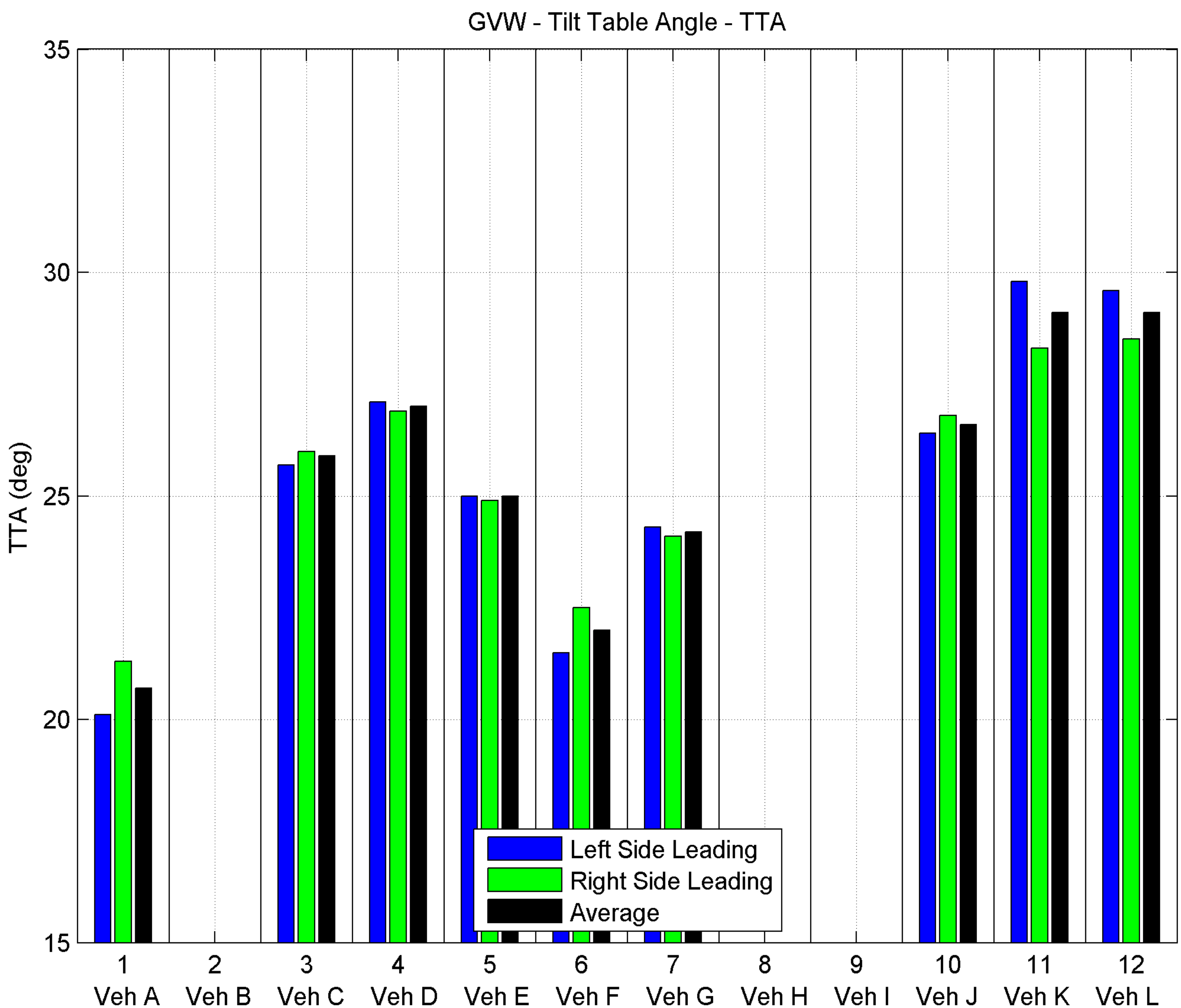


DPI - Tilt Table Ratio - TTR
TTR
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Left Side Leading
Right Side Leading
Average

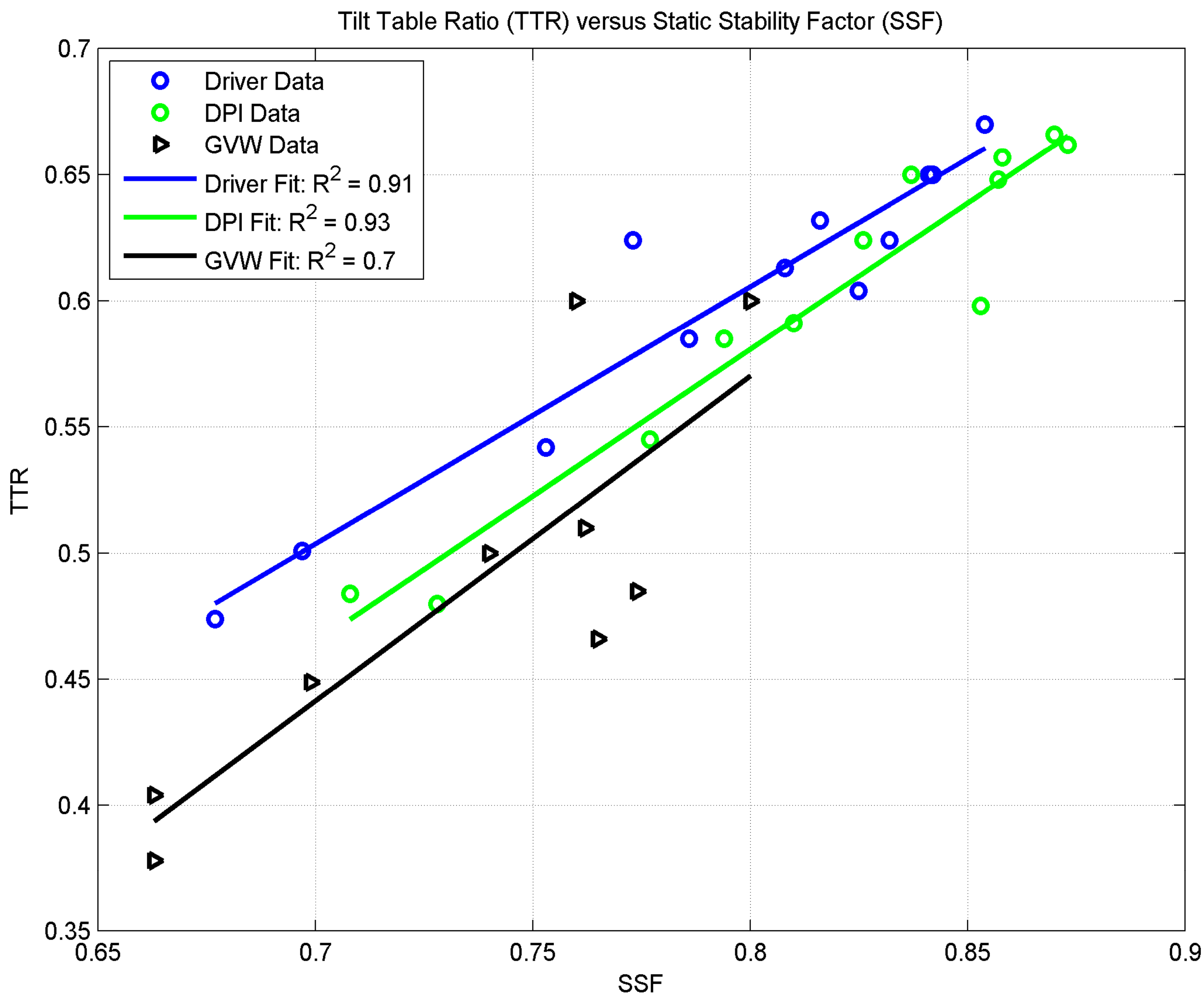

GVW - Tilt Table Ratio - TTR
Left Side Leading
Right Side Leading
Average
TTR
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

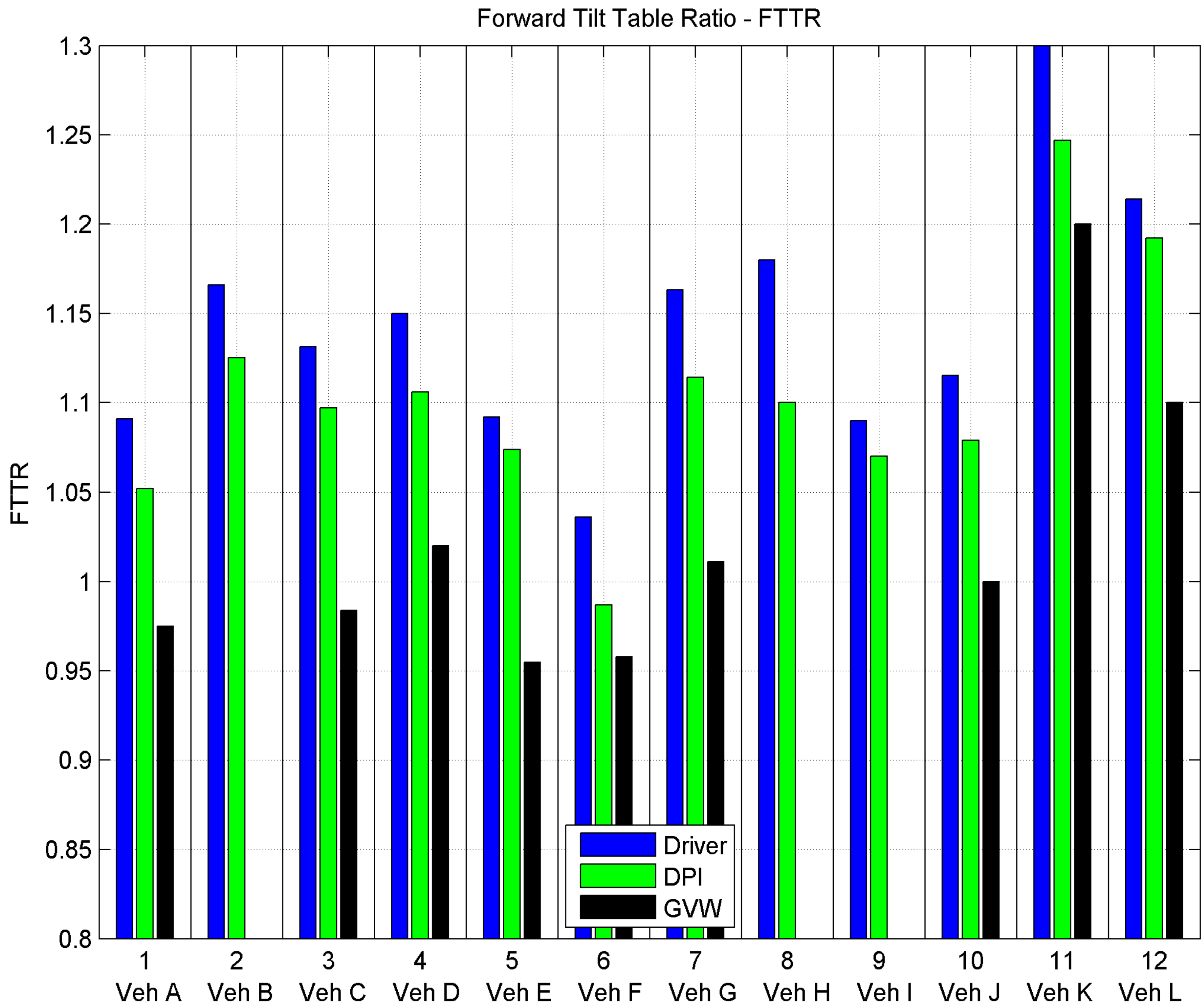

Driver - Tilt Table Angle - TTA
TTA (deg)
35
30
25
20
15
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Left Side Leading
Right Side Leading
Average

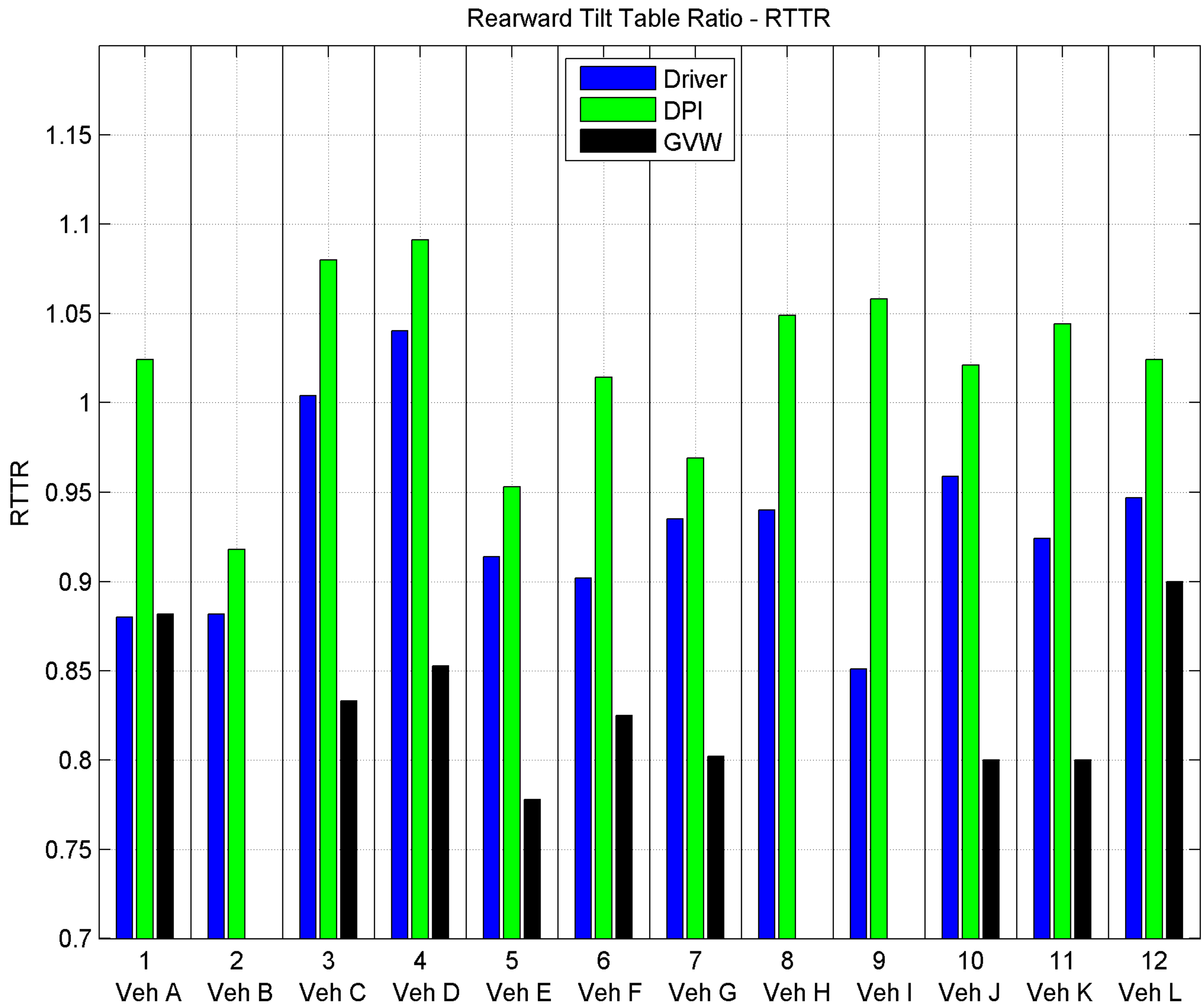

DPI - Tilt Table Angle - TTA
35
30
25
20
15
TTA (deg)
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Left Side Leading
Right Side Leading
Average



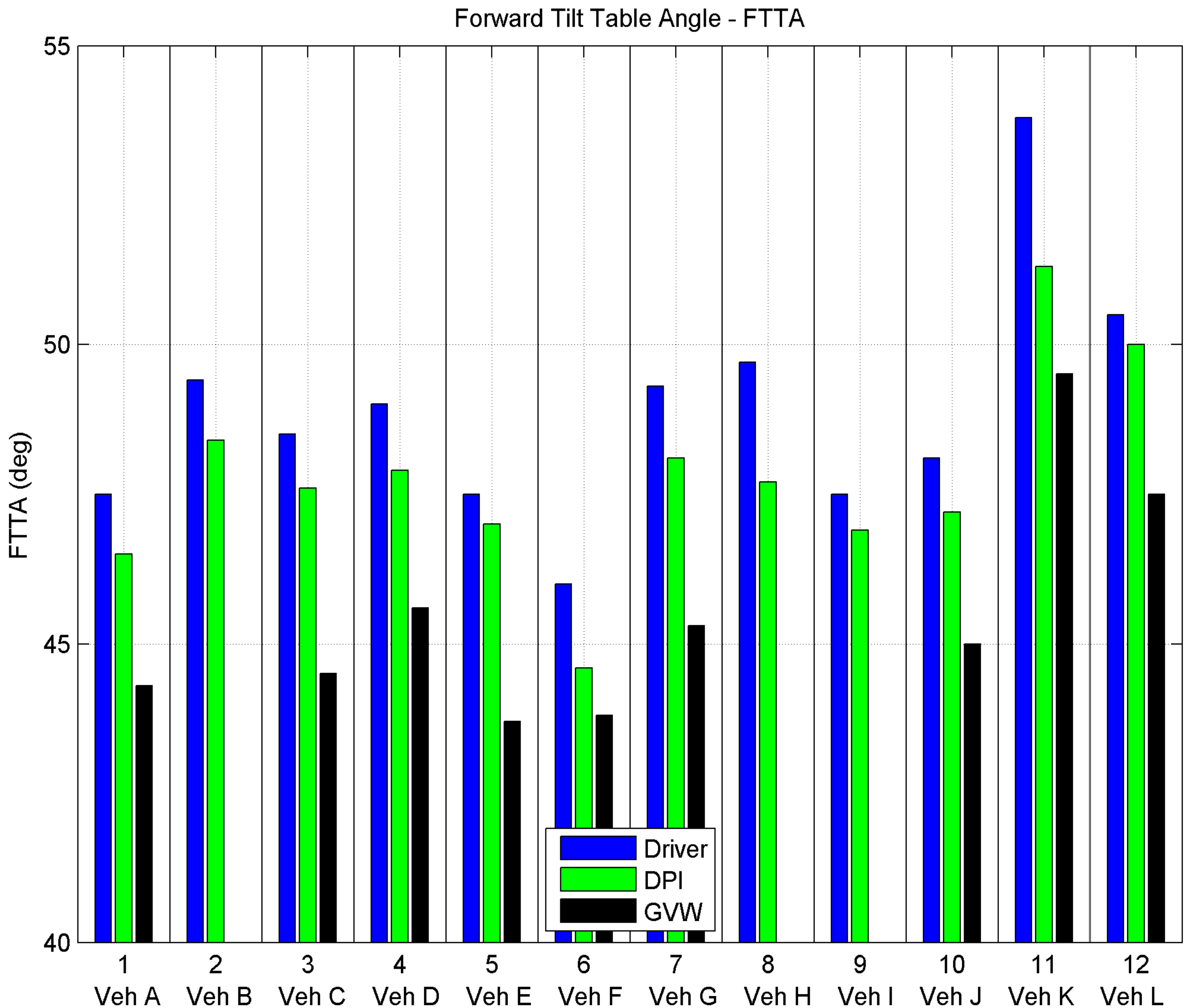
GVW - Tilt Table Angle - TTA
TTA (deg)
35
30
25
20
15
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Left Side Leading
Right Side Leading
Average


Tilt Table Ratio (TTR) versus Static Stability Factor (SSF)
Driver Data
DPI Data
GVW Data
Driver Fit: R^2 = 0.91
DPI Fit: R^2 = 0.93
GVW Fit: R^2 = 0.7
TTR
SSF
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.65
0.7
0.75
0.8
0.85
0.9

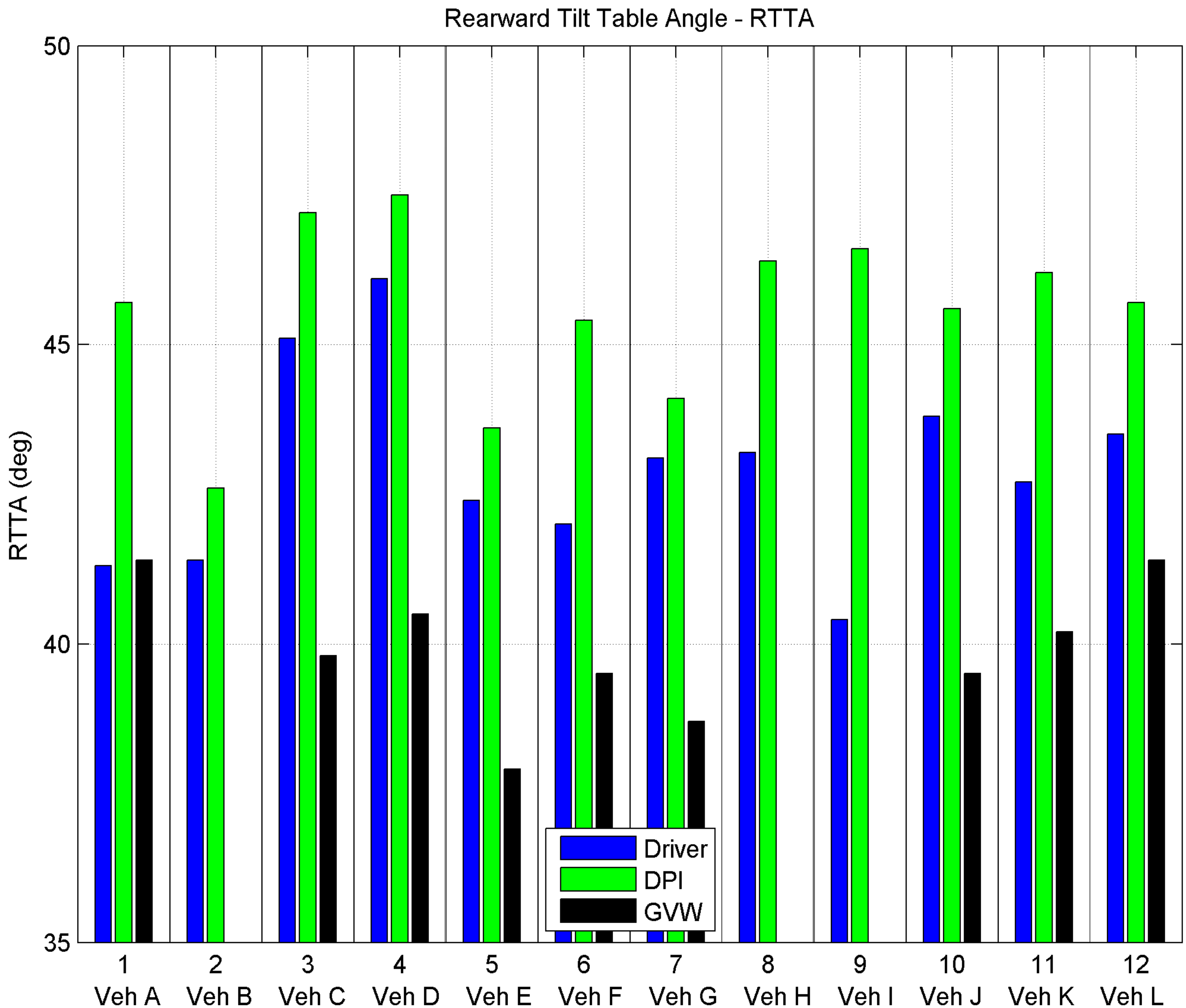

Forward Tilt Table Ratio - FTTR
FTTR
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
Driver
DPI
GVW
1 Veh A
2 Veh B
3 Veh C
4 Veh D
5 Veh E
6 Veh F
7 Veh G
8 Veh H
9 Veh I
10 Veh J
11 Veh K
12 Veh L

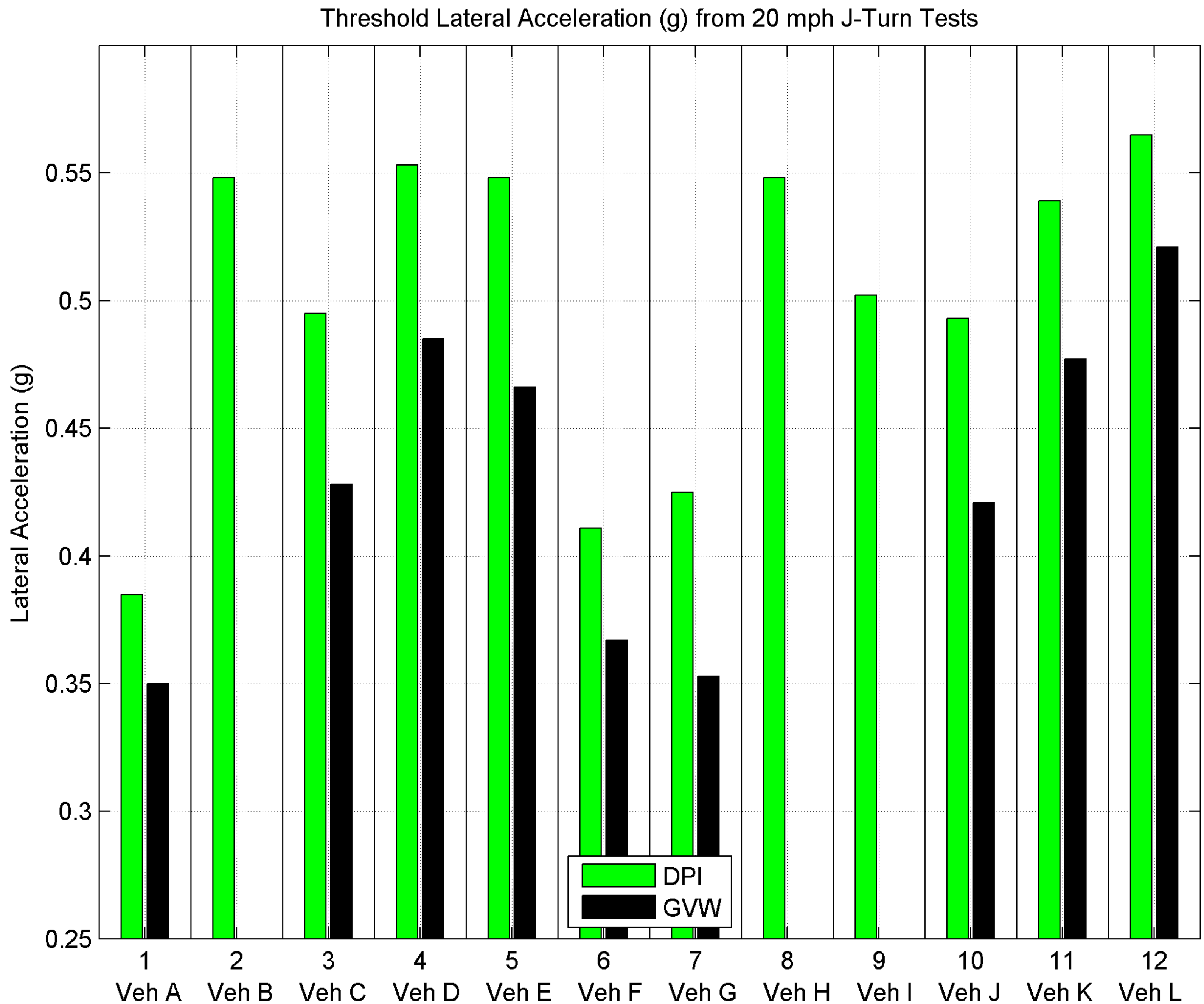


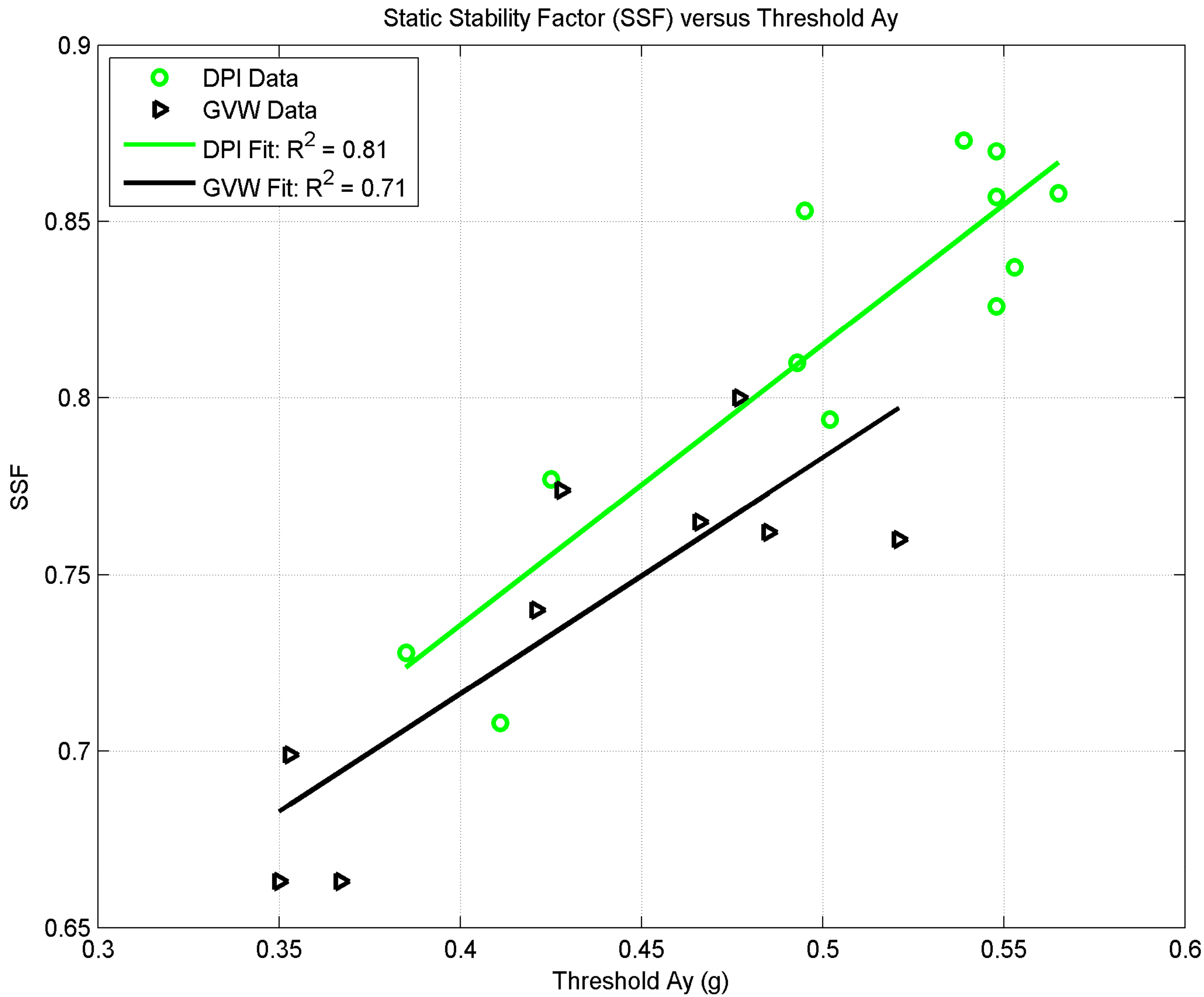
Rearward Tilt Table Ratio - RTTR
Driver
DPI
GVW
RTTR
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

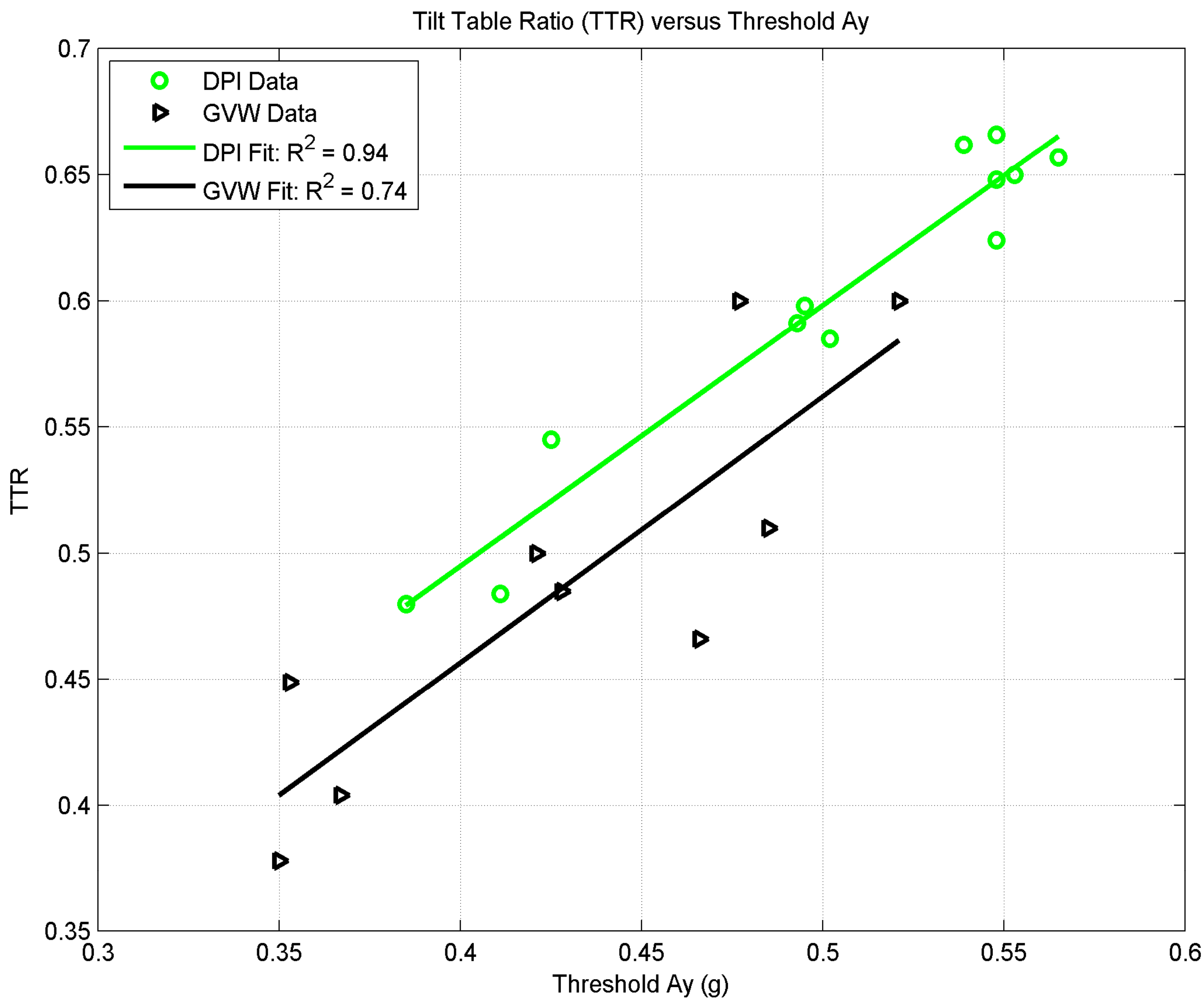


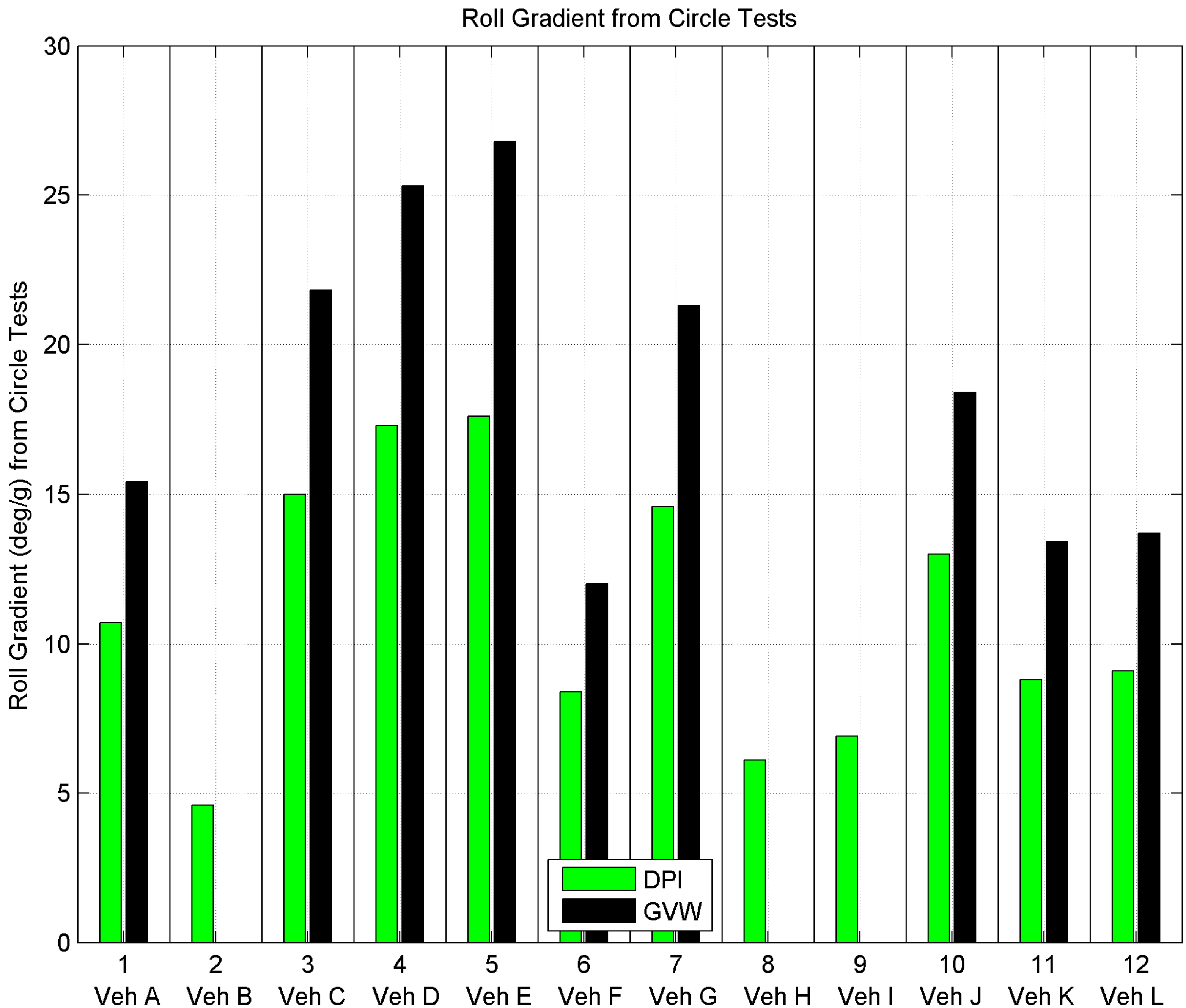
Forward Tilt Table Angle - FTTA
FTTA (deg)
55
50
45
40
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Driver
DPI
GVW

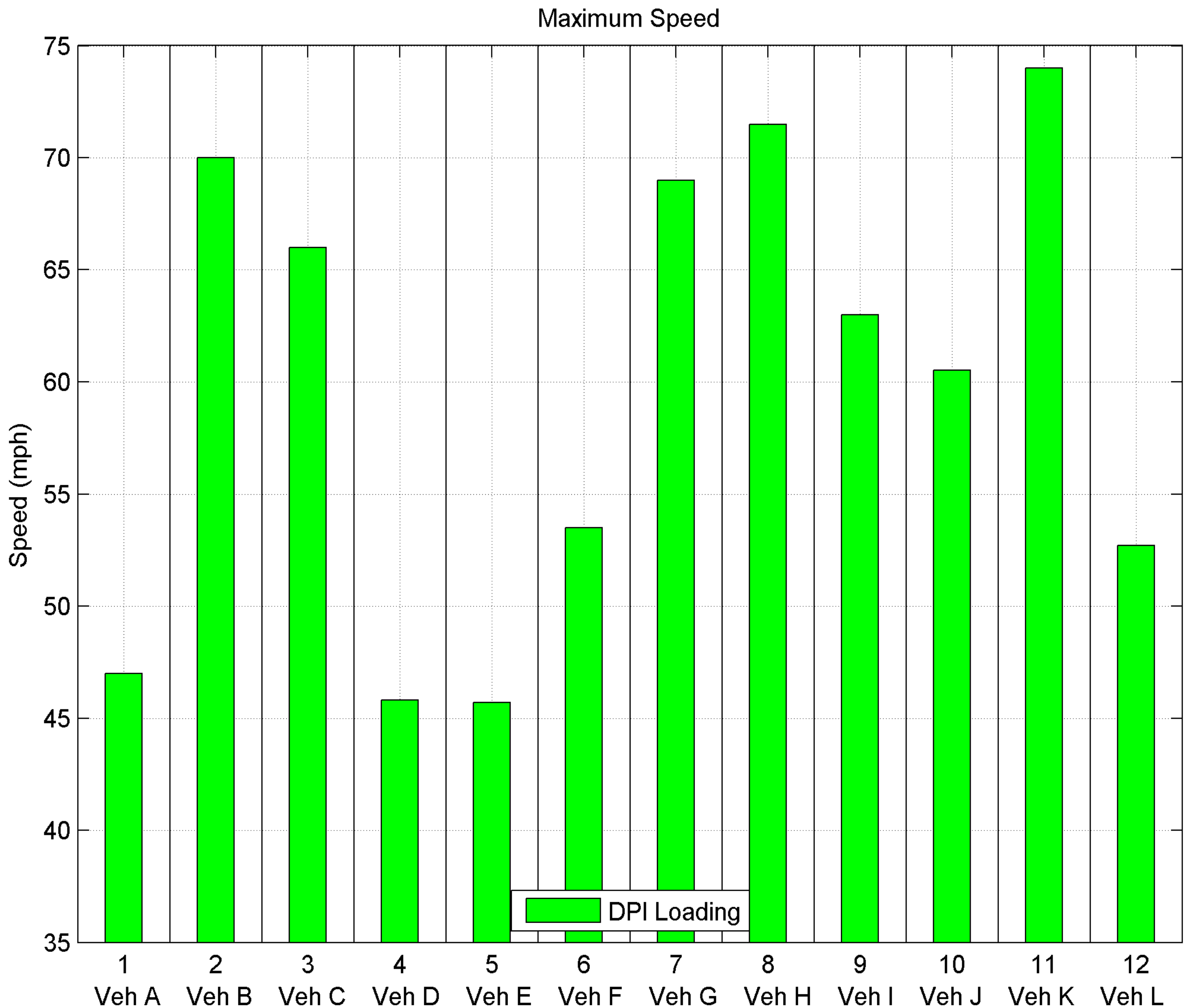

Rearward Tilt Table Angle - RTTA
50
45
40
35
RTTA (deg)
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
Driver
DPI
GVW


Threshold Lateral Acceleration (g) from 20 mph J-Turn Tests
Lateral Acceleration (g)
0.55
0.5
0.45
0.4
0.35
0.3
0.25
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L
DPI
GVW


Static Stability Factor (SSF) versus Threshold Ay
DPI Data
GVW Data
DPI Fit: R2 = 0.81
GVW Fit: R2 = 0.71
SSF
Threshold Ay (g)
0.9
0.85
0.8
0.75
0.7
0.65
0.3
0.35
0.4
0.45
0.5
0.55
0.6


Tilt Table Ratio (TTR) versus Threshold Ay
DPI Data
GVW Data
DPI Fit: R^2 = 0.94
GVW Fit: R^2 = 0.74
TTR
Threshold Ay (g)
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.35
0.4
0.45
0.5
0.55
0.6


Roll Gradient from Circle Tests
Roll Gradient (deg/g) from Circle Tests
30
25
20
15
10
5
0
DPI
GVW
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L


Maximum Speed
Speed (mph)
75
70
65
60
55
50
45
40
35
DPI Loading
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

Constant Radius (50 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (DPI Loading)			
	CW (g)	CCW (g)	Average (g)
Vehicle A	0.17	0.16	0.16
Vehicle B	0.19	0.18	0.18
Vehicle C	0.23	0.19	0.21
Vehicle D	NA	NA	NA
Vehicle E	NA	NA	NA
Vehicle F	0.12	0.14	0.13
Vehicle G	0.21	0.16	0.18
Vehicle H	0.13	0.14	0.13
Vehicle I	0.13	0.13	0.13
Vehicle J	0.16	0.15	0.15
Vehicle K	0.24	0.25	0.24
Vehicle L	0.26	0.22	0.24

Constant Radius (50 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (GVW Loading)			
	CW (g)	CCW (g)	Average (g)
Vehicle A	0.15	0.15	0.15
Vehicle C	0.21	0.17	0.19
Vehicle D	NA	NA	NA
Vehicle E	NA	NA	NA
Vehicle F	0.11	0.12	0.11
Vehicle G	0.16	0.13	0.14
Vehicle J	0.14	0.12	0.13
Vehicle K	0.23	0.23	0.23
Vehicle L	0.32	0.24	0.28

Constant Speed (20 mph) Slowly Increasing Steer Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (DPI Loading)			
	Right Turn (g)	Left Turn (g)	Average (g)
Vehicle A	0.31	0.23	0.27
Vehicle B	0.32	0.29	0.31
Vehicle C	0.40	0.38	0.39
Vehicle D	NA	NA	NA
Vehicle E	NA	NA	NA
Vehicle F	0.24	0.21	0.23
Vehicle G	0.36	NA	NA
Vehicle H	0.31	0.30	0.31
Vehicle I	0.35	0.36	0.36
Vehicle J	0.32	0.32	0.32
Vehicle K	NA	NA	NA
Vehicle L	NA	NA	NA

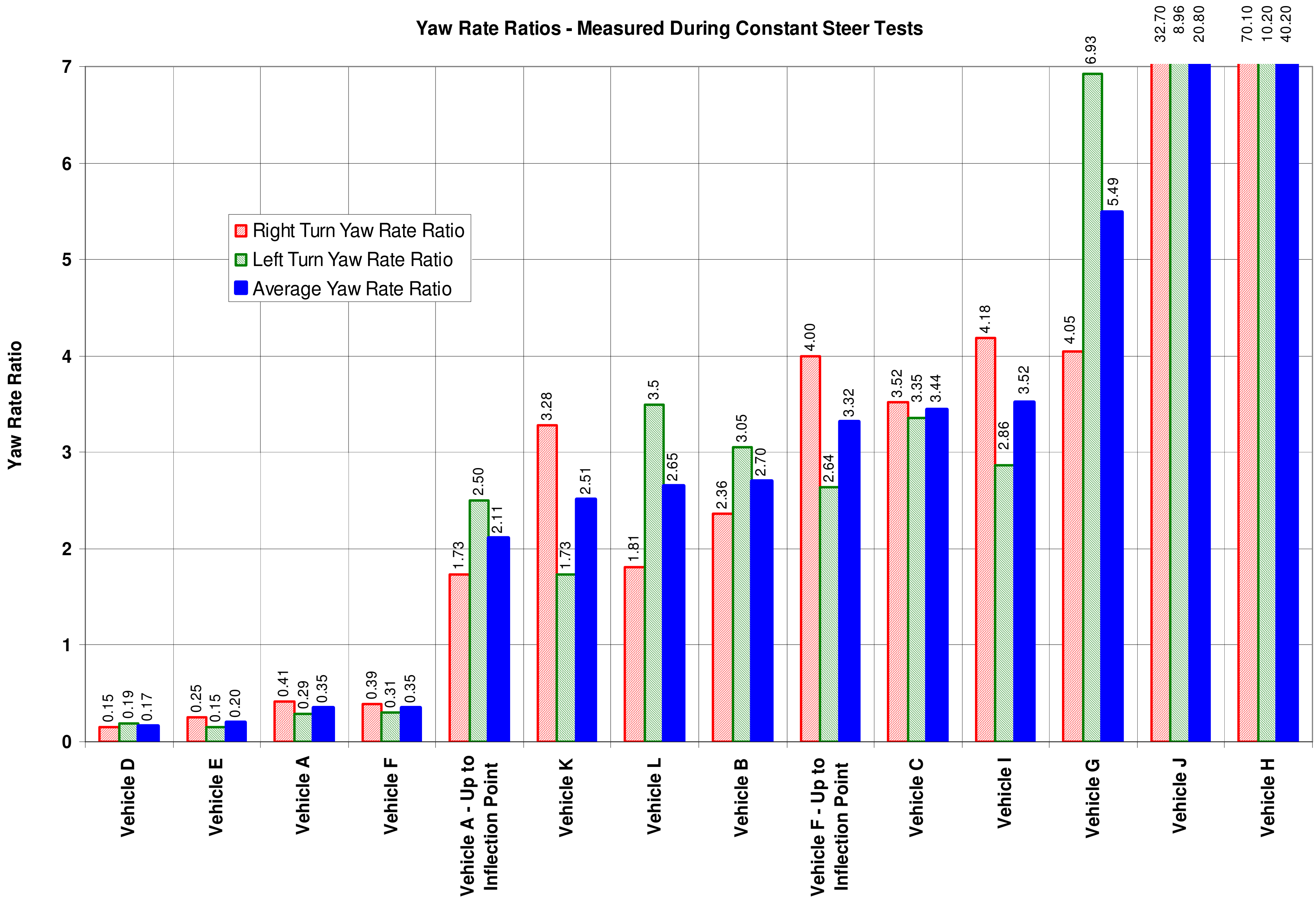
<u>20 mph Dropped Throttle J-Turn Tests</u>
Threshold Lateral Acceleration
(DPI Loading)

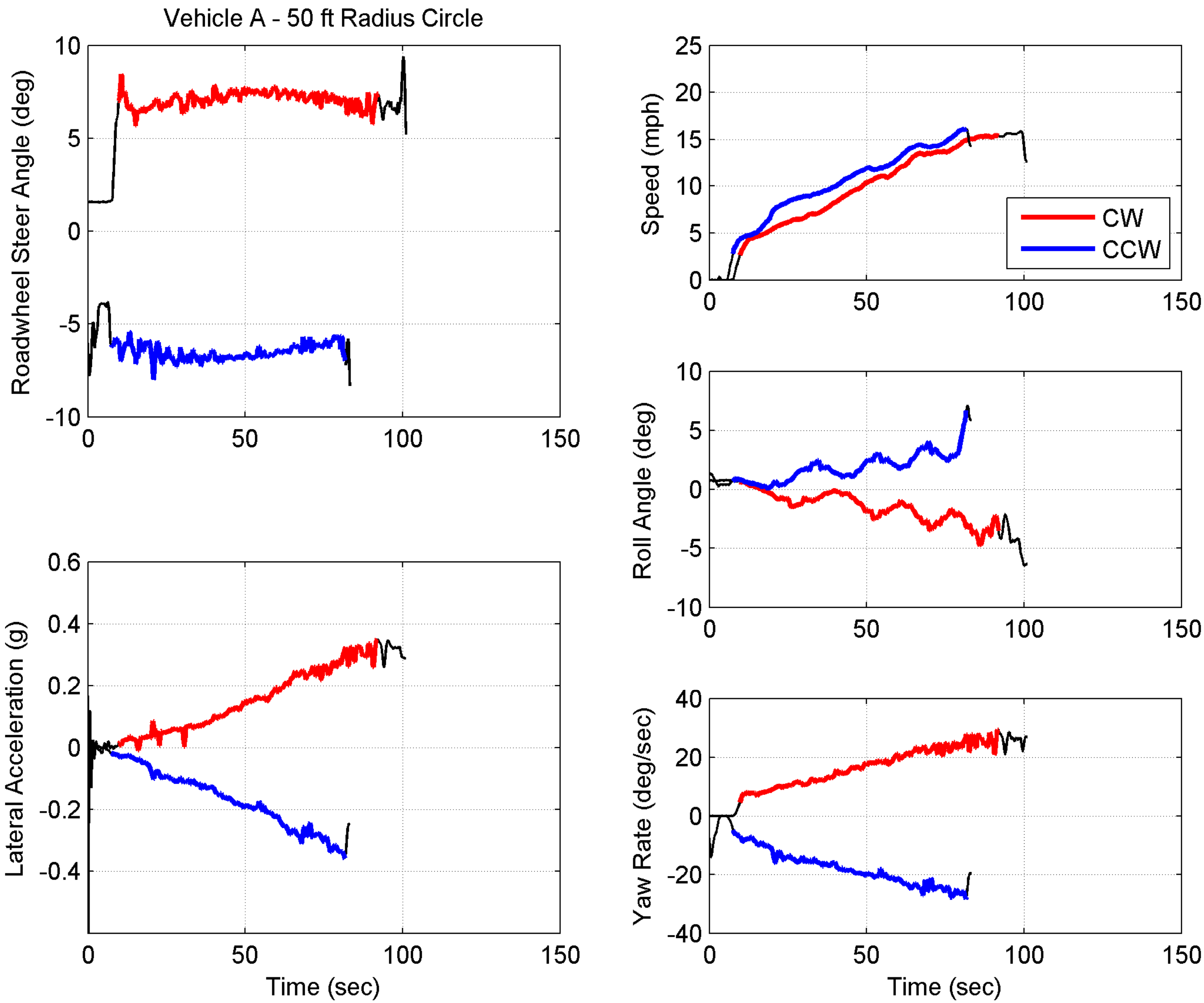
	Threshold Lateral Acceleration (g)
Vehicle A	0.38
Vehicle B	0.55
Vehicle C	0.50
Vehicle D	0.55
Vehicle E	0.55
Vehicle F	0.41
Vehicle G	0.43
Vehicle H	0.55
Vehicle I	0.50
Vehicle J	0.49
Vehicle K	0.54
Vehicle L	0.56

20 mph Dropped Throttle J-Turn Tests
Threshold Lateral Acceleration
(GVW Loading)

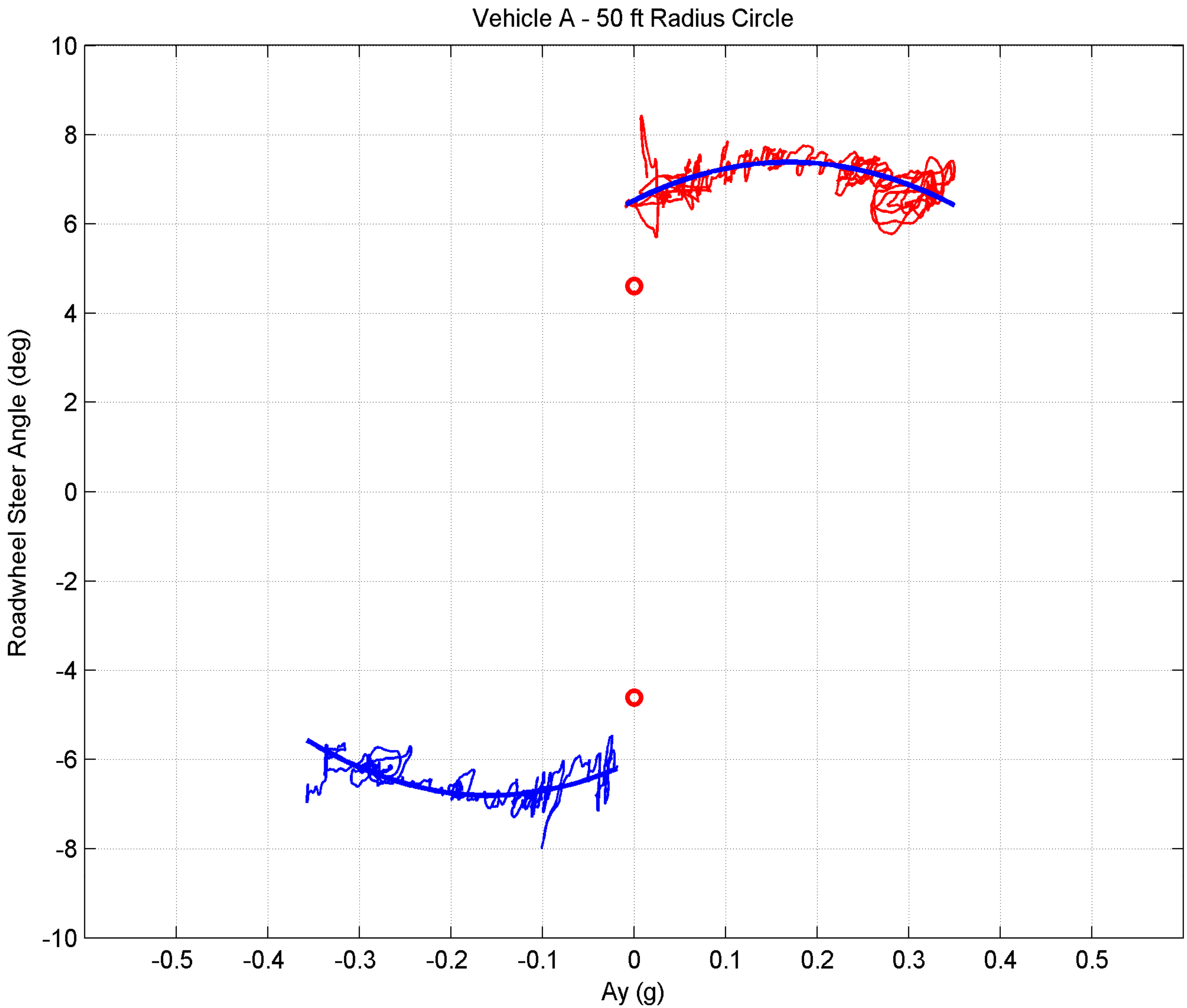
	Threshold Lateral Acceleration (g)
Vehicle A	0.35
Vehicle C	0.43
Vehicle D	0.48
Vehicle E	0.47
Vehicle F	0.37
Vehicle G	0.35
Vehicle J	0.42
Vehicle K	0.48
Vehicle L	0.52

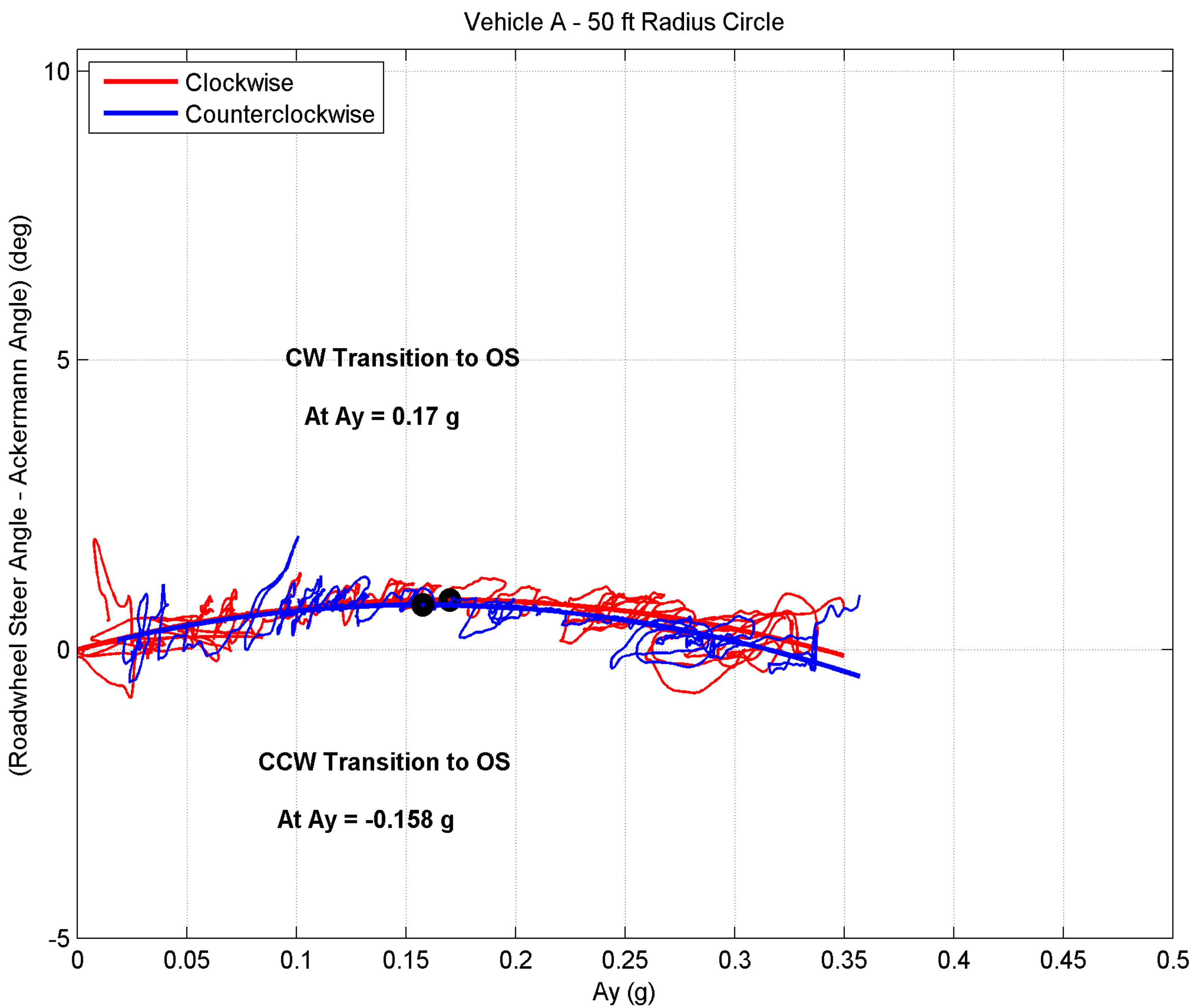
Constant Steer Tests Yaw Rate Ratios (DPI Loading)			
	Right Turn (g)	Left Turn (g)	Average (g)
Vehicle A	0.41	0.29	0.35
Vehicle A – Up To Inflection Point	1.73	2.50	2.11
Vehicle B	2.36	3.05	2.70
Vehicle C	3.52	3.35	3.44
Vehicle D	0.15	0.19	0.17
Vehicle E	0.25	0.15	0.20
Vehicle F	0.39	0.31	0.35
Vehicle F – Up To Inflection Point	4.00	2.64	3.32
Vehicle G	4.05	6.93	5.49
Vehicle H	70.10	10.20	40.20
Vehicle I	4.18	2.86	3.52
Vehicle J	32.70	8.96	20.80
Vehicle K	3.28	1.73	2.51
Vehicle L	1.81	3.50	2.65

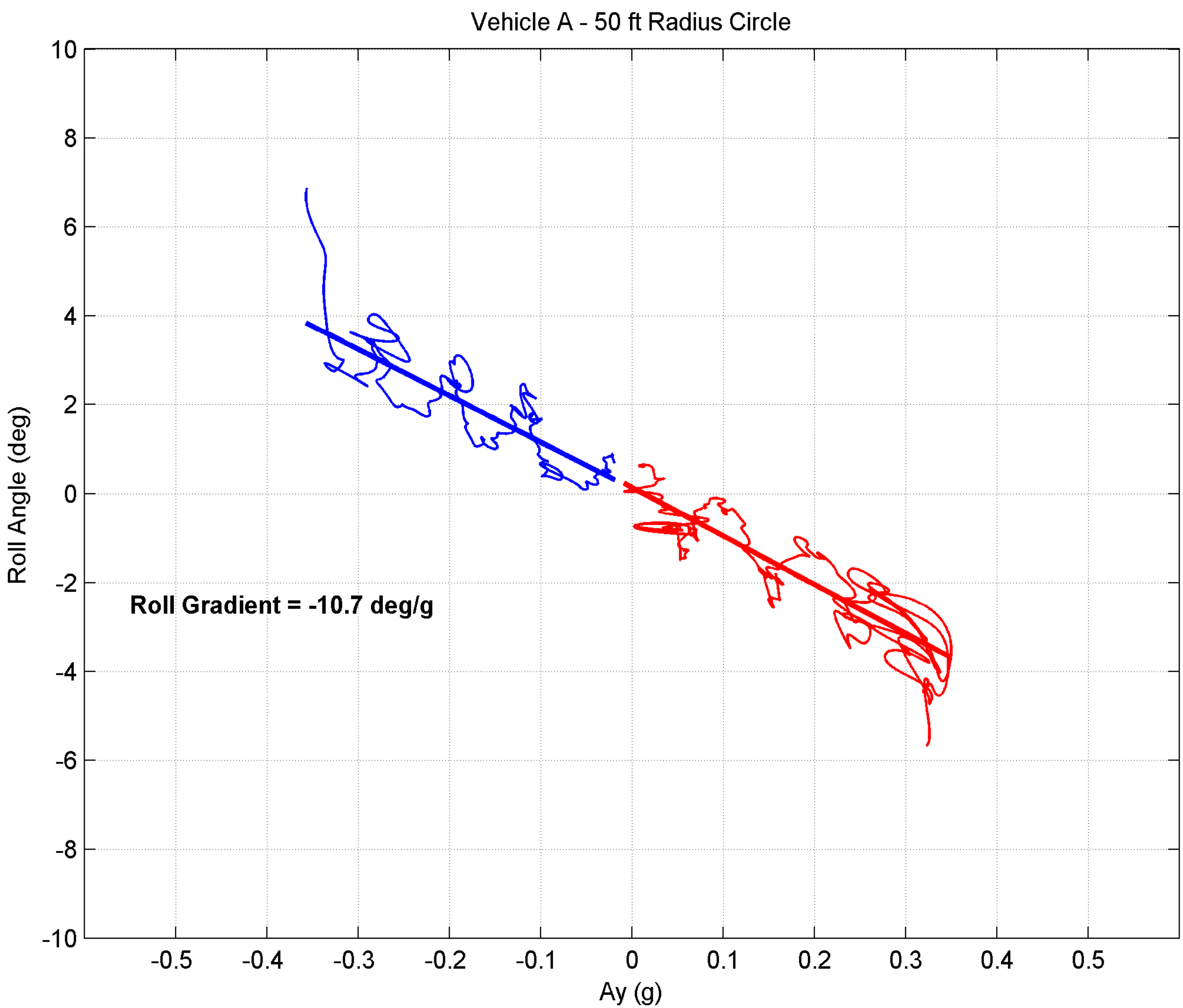

Yaw Rate Ratios - Measured During Constant Steer Tests
Yaw Rate Ratio
Right Turn Yaw Rate Ratio
Left Turn Yaw Rate Ratio
Average Yaw Rate Ratio
0
1
2
3
4
5
6
7
0.15
0.19
0.17
0.25
0.15
0.20
0.41
0.29
0.35
0.39
0.31
0.35
1.73
2.50
2.11
3.28
1.73
2.51
1.81
3.5
2.65
2.36
3.05
2.70
4.00
2.64
3.32
3.52
3.35
3.44
4.18
2.86
3.52
4.05
6.93
5.49
32.70
8.96
20.80
70.10
10.20
40.20
Vehicle D
Vehicle E
Vehicle A
Vehicle F
Vehicle A - Up to Inflection Point
Vehicle K
Vehicle L
Vehicle B
Vehicle F - Up to Inflection Point
Vehicle C
Vehicle I
Vehicle G
Vehicle J
Vehicle H

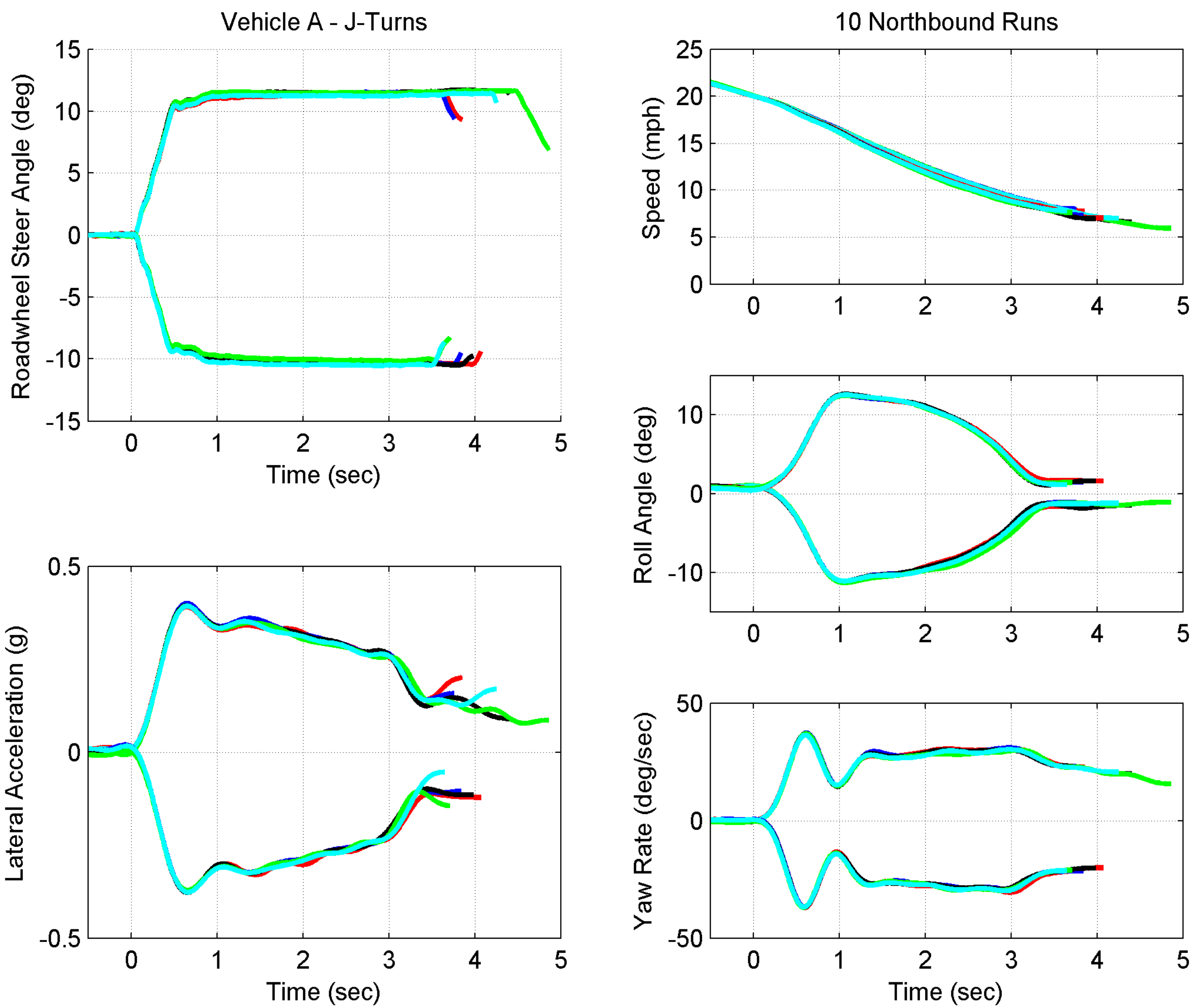


Vehicle A - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
CW
CCW
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

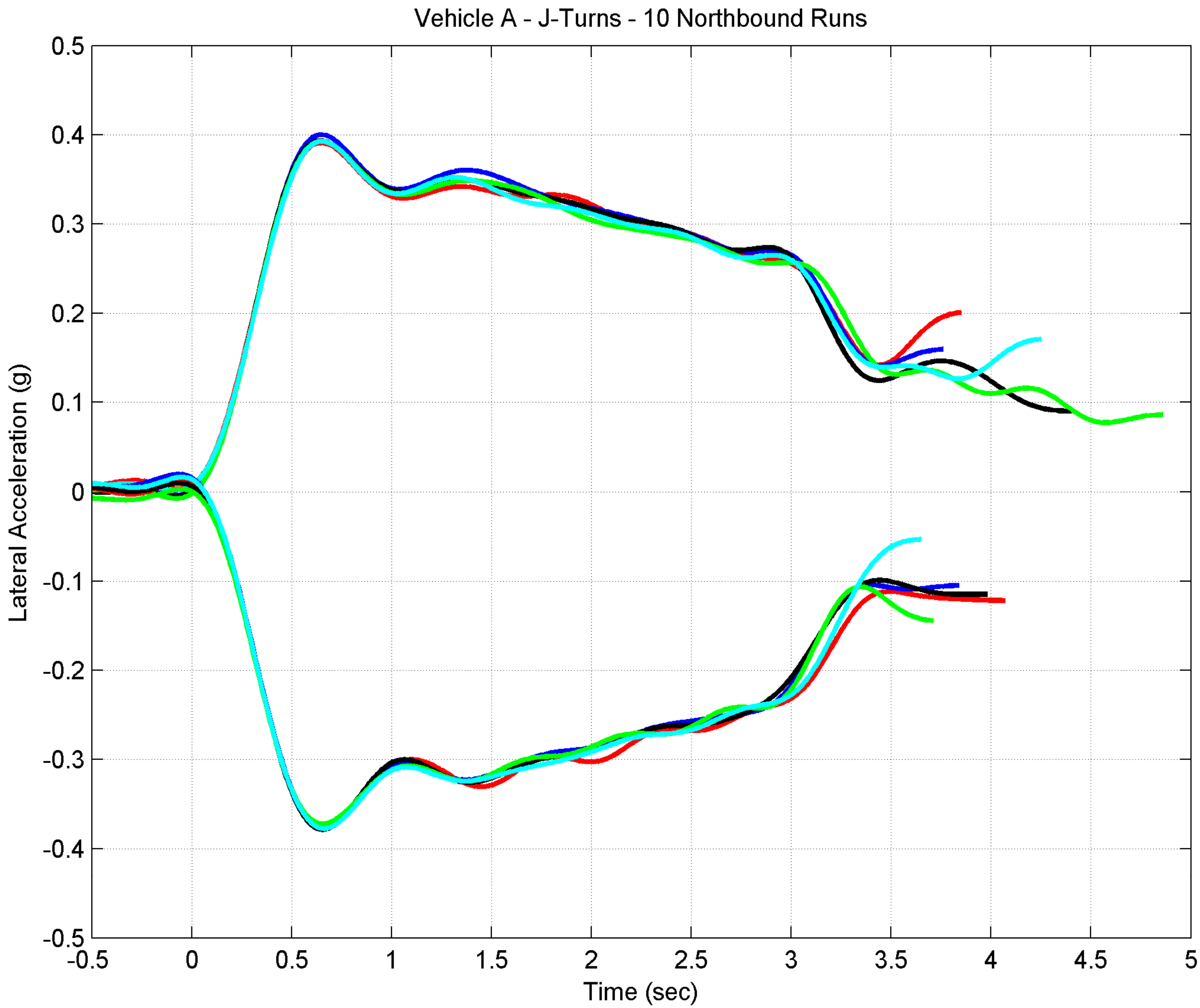

Vehicle A - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)


Vehicle A - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.17 g
CCW Transition to OS
At Ay = -0.158 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

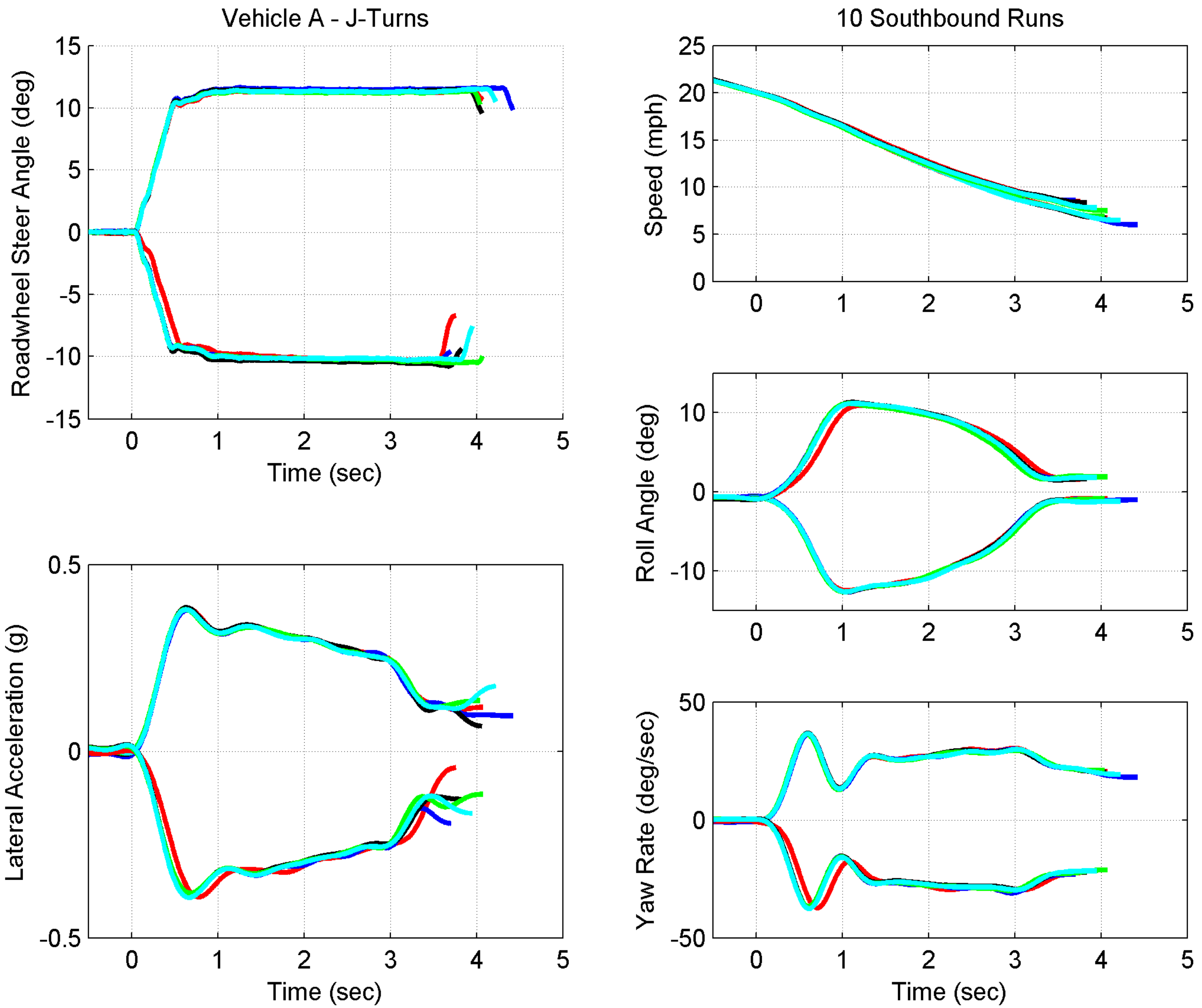

Vehicle A - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -10.7 deg/g
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

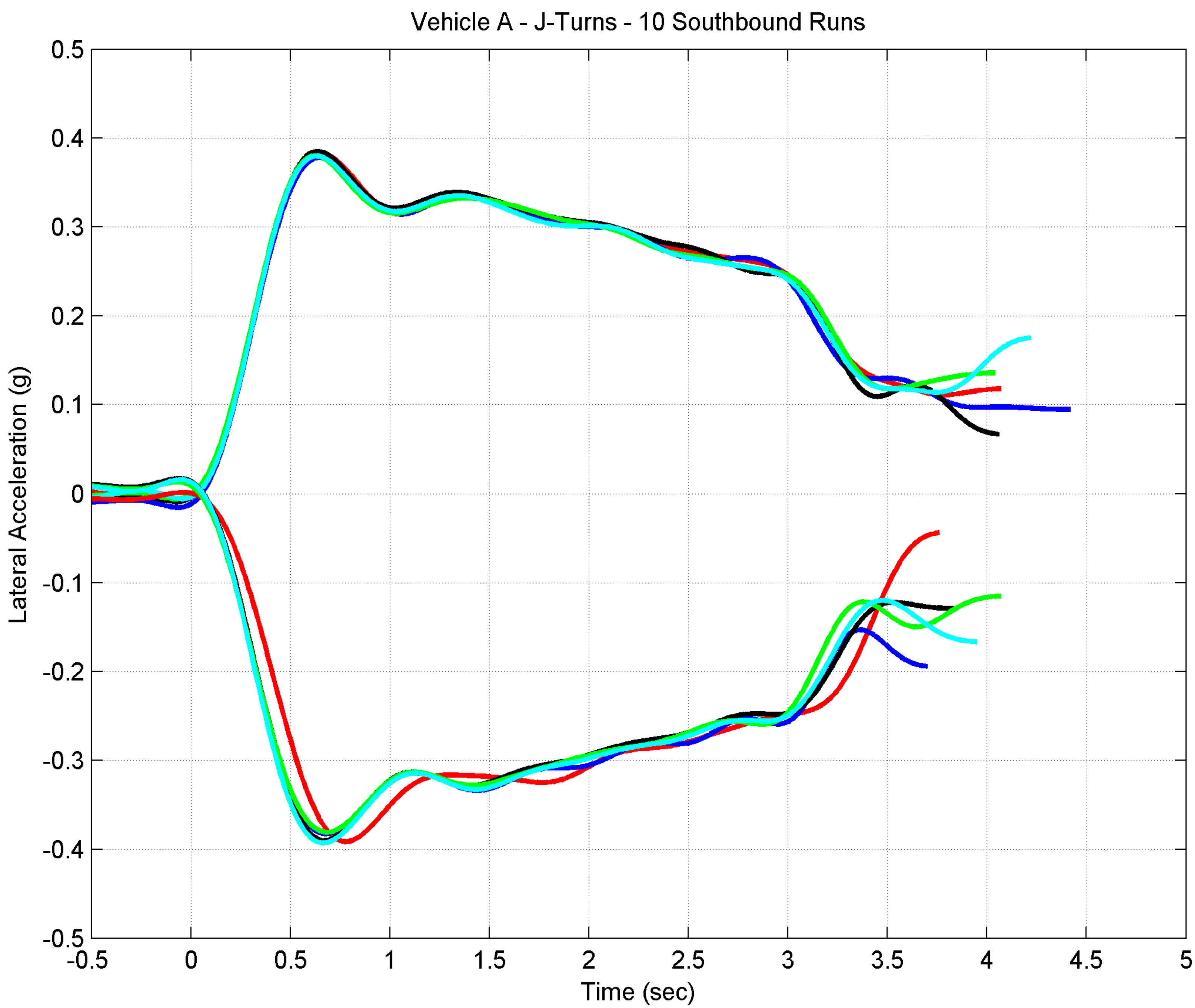


Vehicle A - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)
Speed (mph)
25
20
15
10
5
0
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
50
0
-50



Vehicle A - J-Turns - 10 Northbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle A - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)


Vehicle A - J-Turns - 10 Southbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle A

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.3912	-0.3763
2	0.4003	-0.3751
3	0.3936	-0.3786
4	0.3930	-0.3722
5	0.3929	-0.3775
Mean Value of 5 Runs	0.3942	-0.3759
Standard Deviation of 5 Runs	0.004	0.002

Average of 10 Northbound Runs

0.3851

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.3829	-0.3914
2	0.3778	-0.3826
3	0.3852	-0.3902
4	0.3799	-0.3808
5	0.3796	-0.3929
Mean Value of 5 Runs	0.3811	-0.3876
Standard Deviation of 5 Runs	0.003	0.005

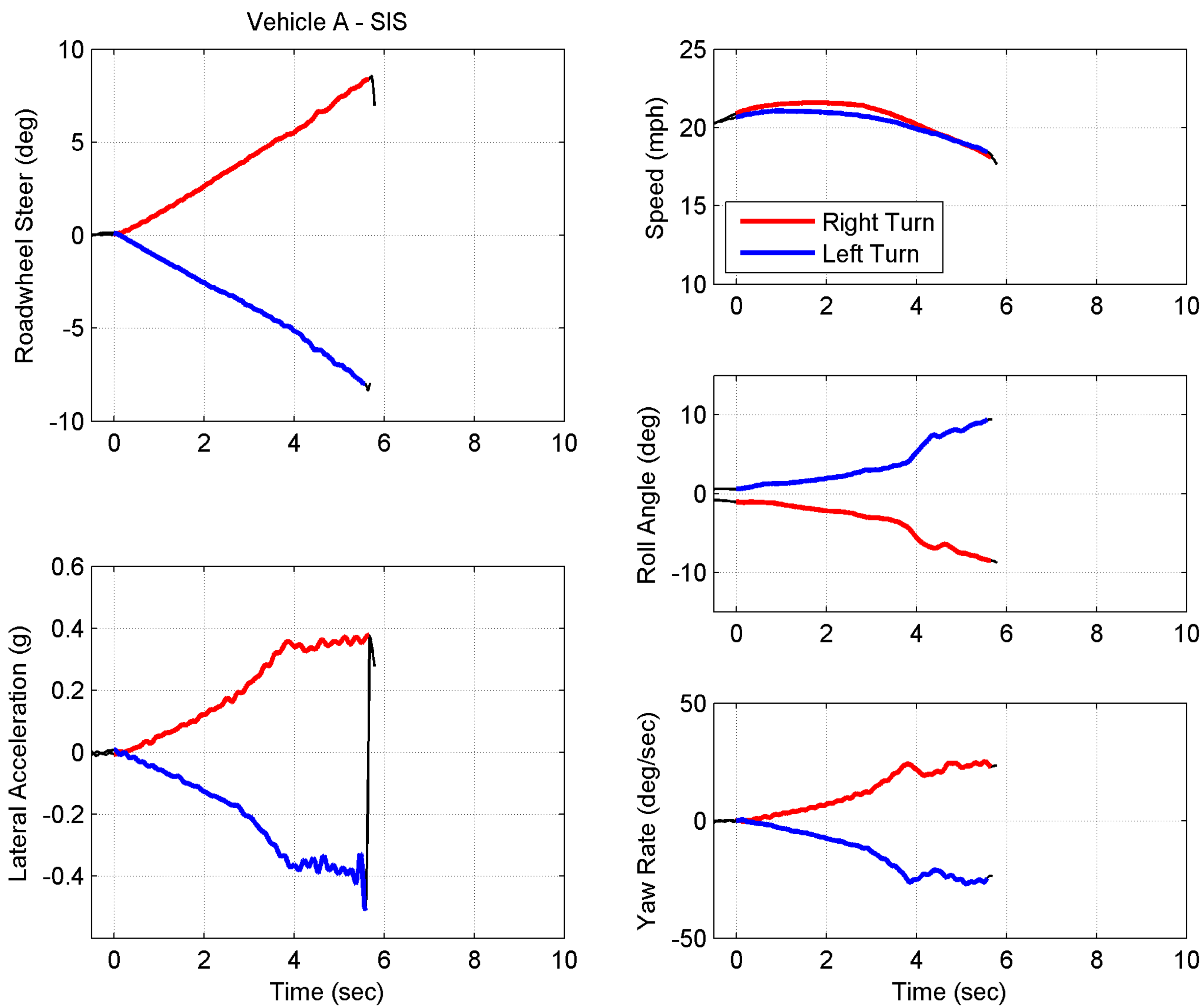
Average of 10 Southbound Runs

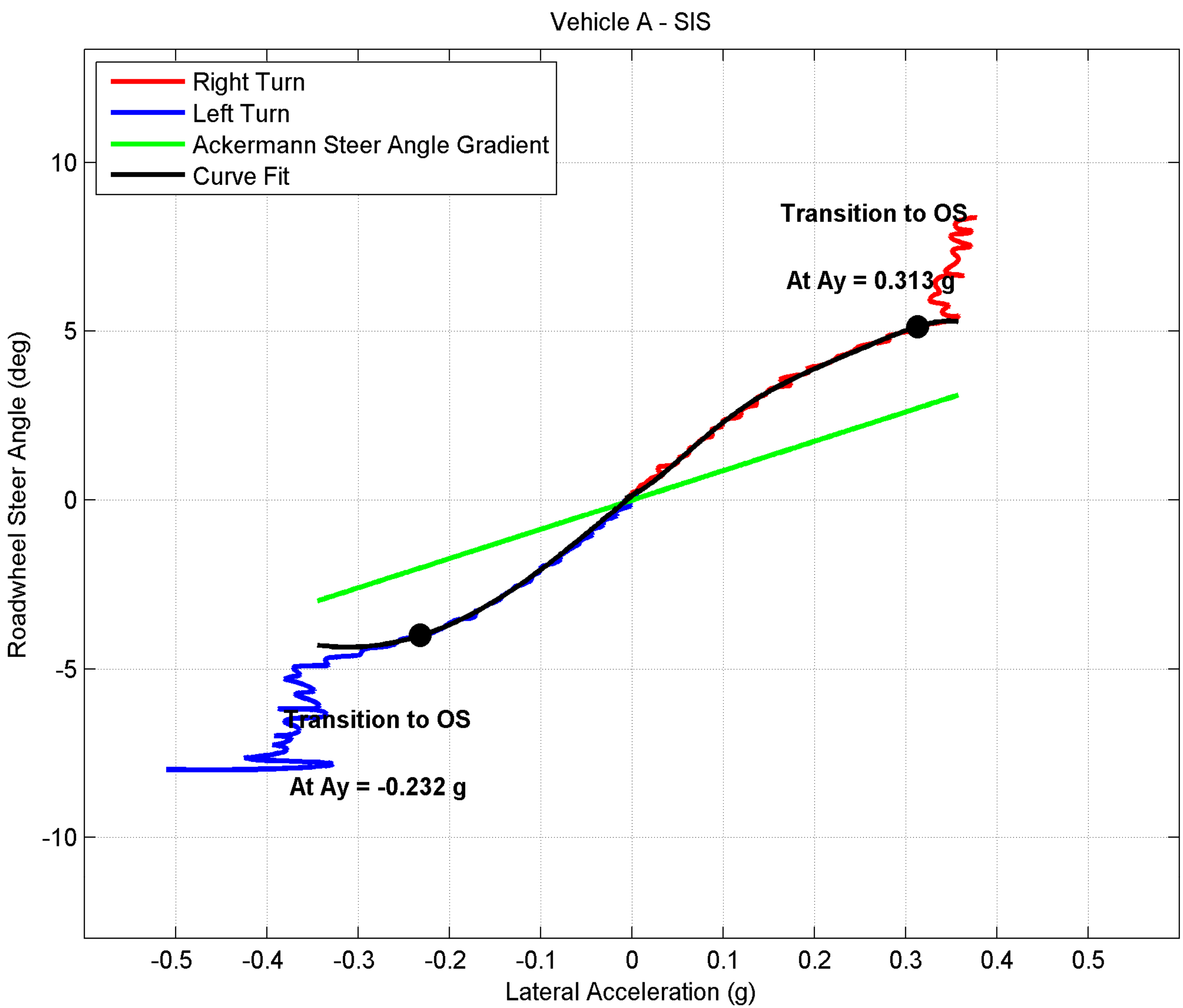
0.3843

Average of All 20 Runs

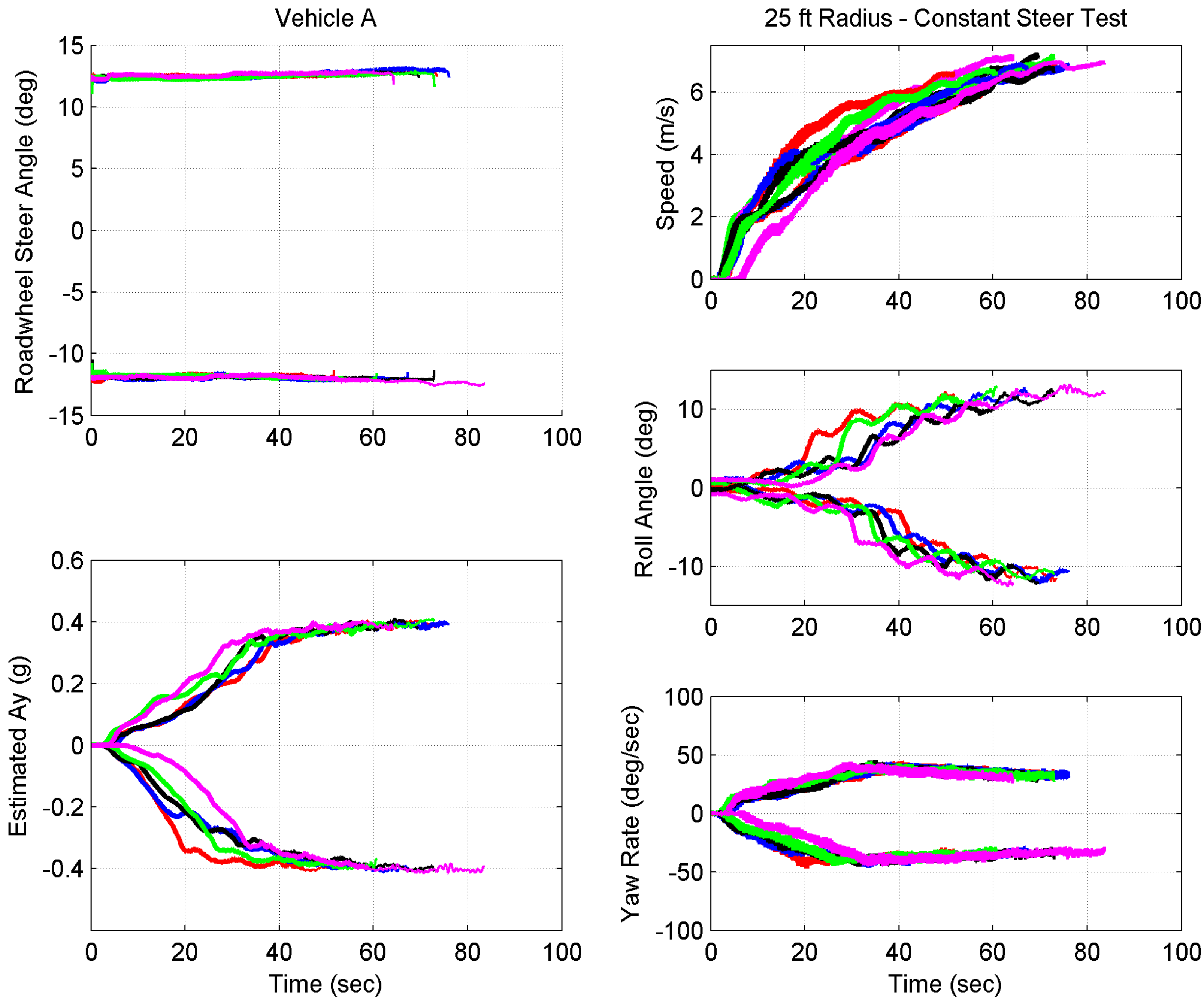
0.385

Threshold Ay

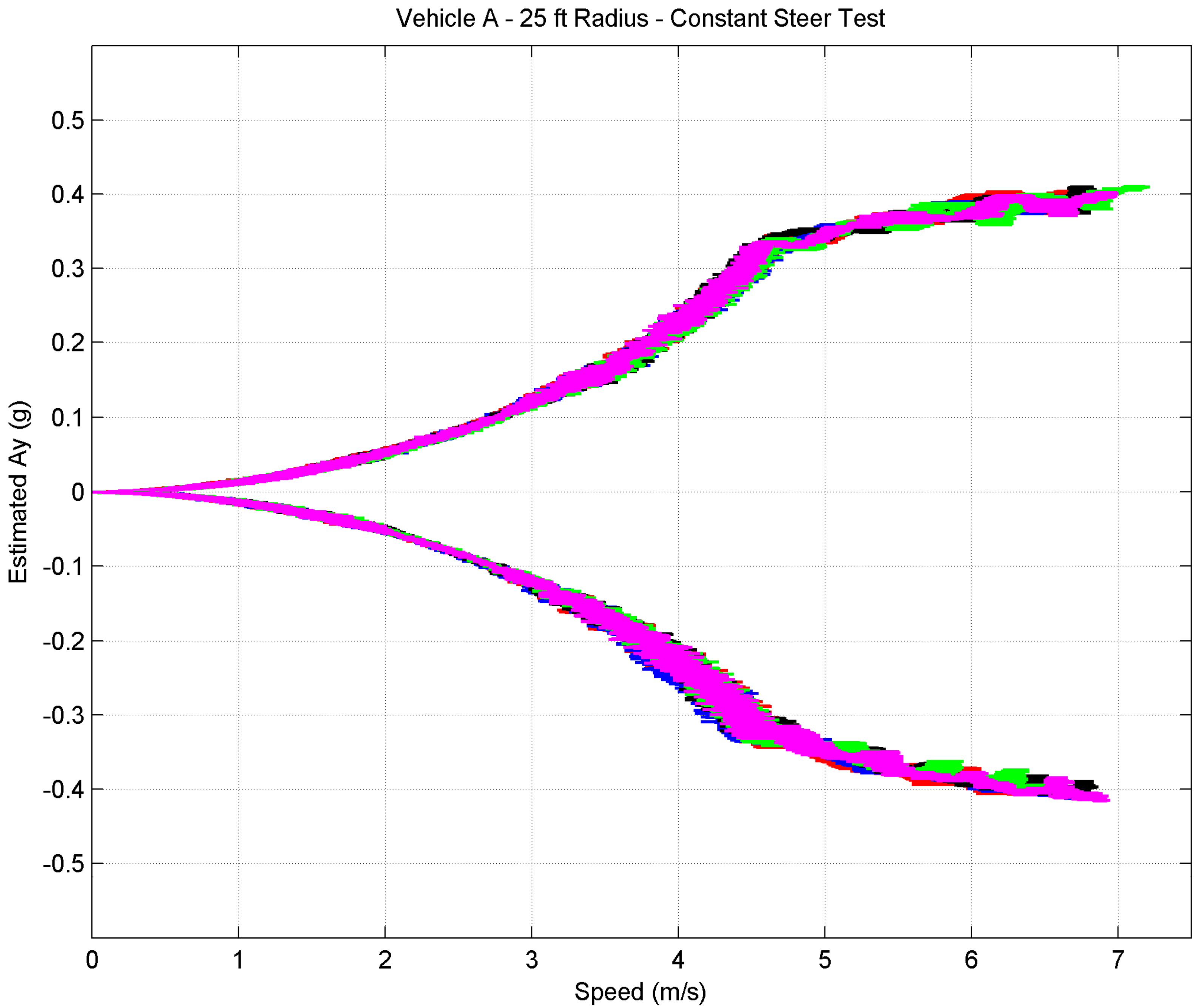

Vehicle A - SIS
Roadwheel Steer (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

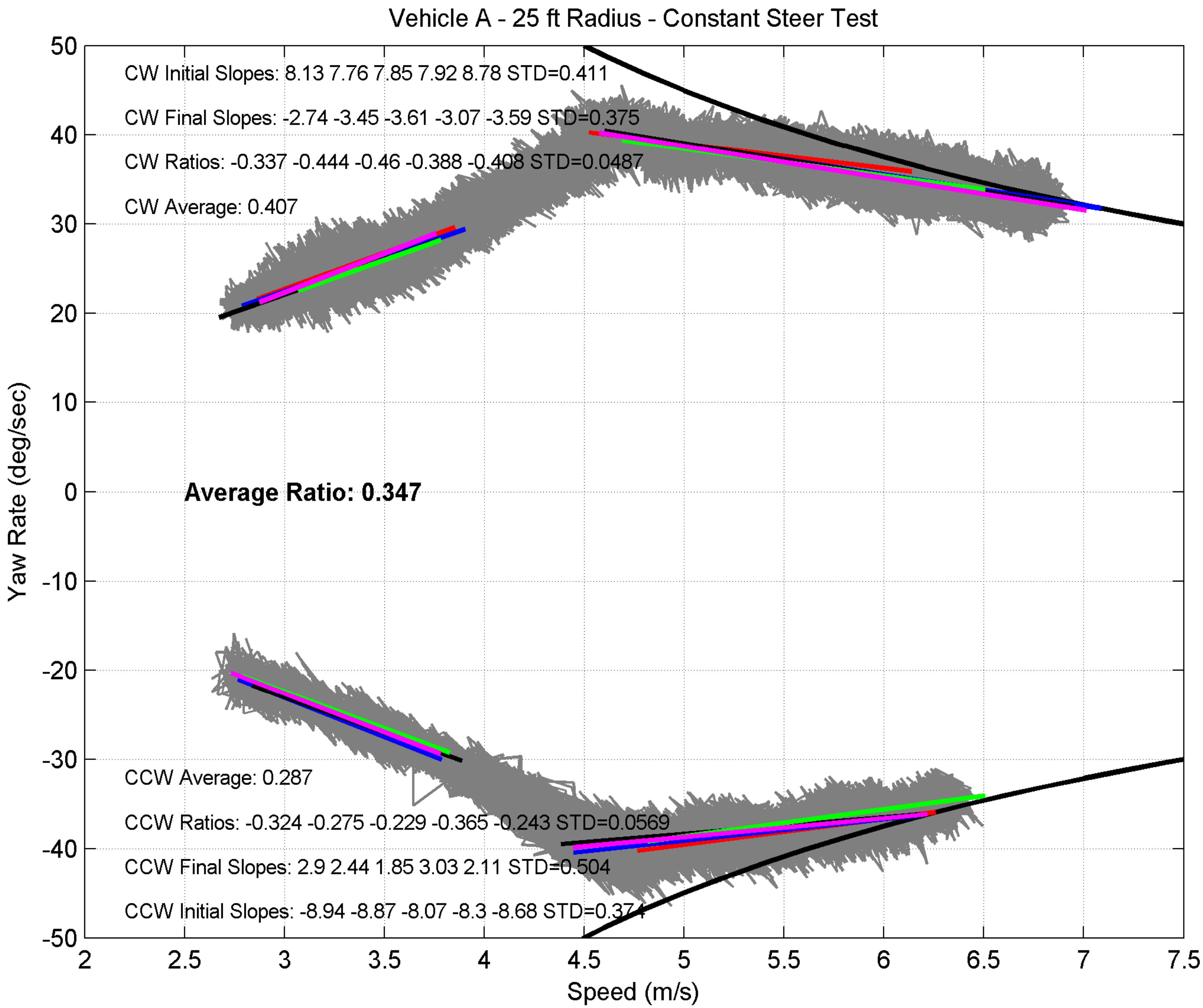


Vehicle A - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to OS
At Ay = 0.313 g
Transition to OS
At Ay = -0.232 g
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
10
5
0
-5
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

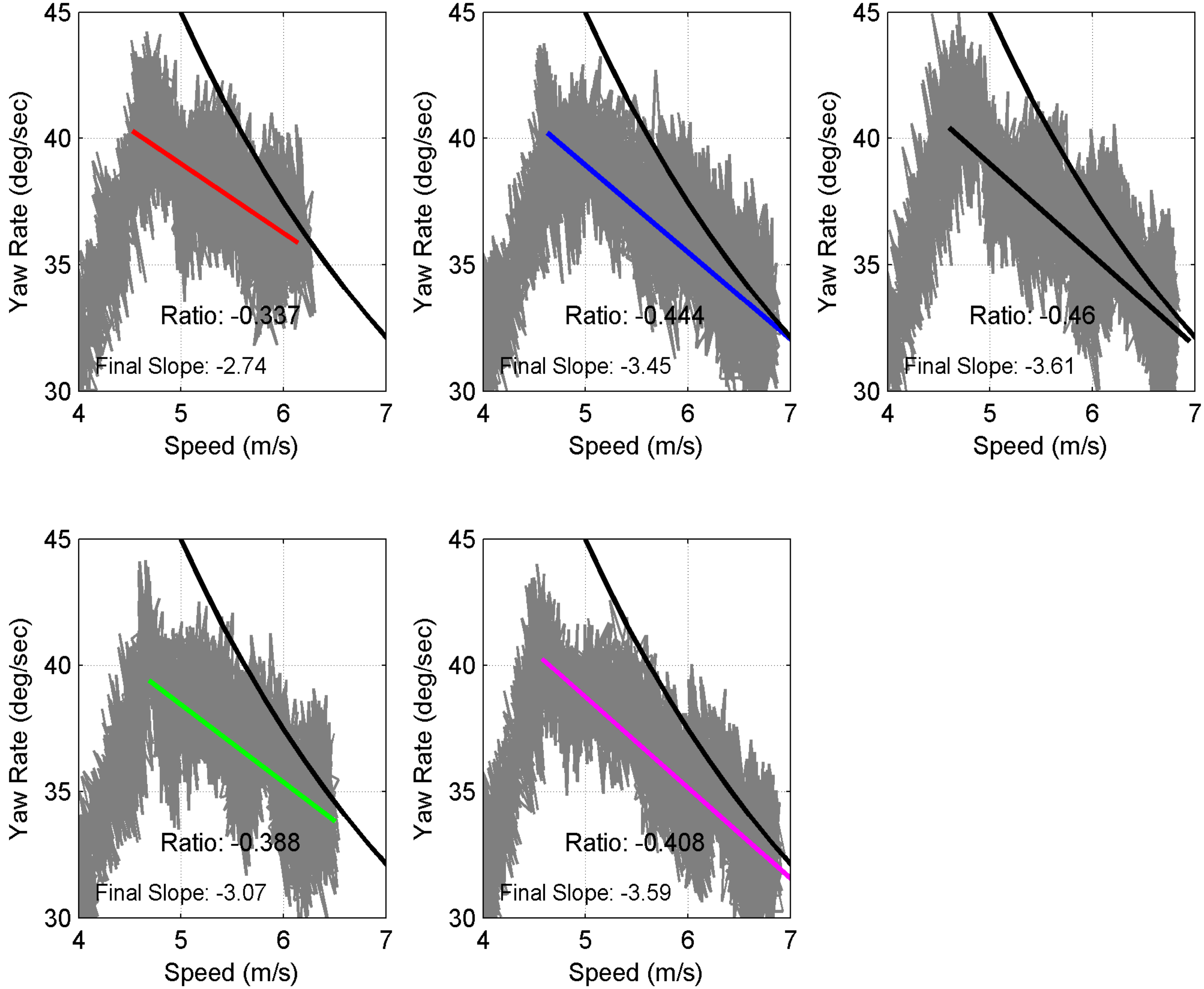


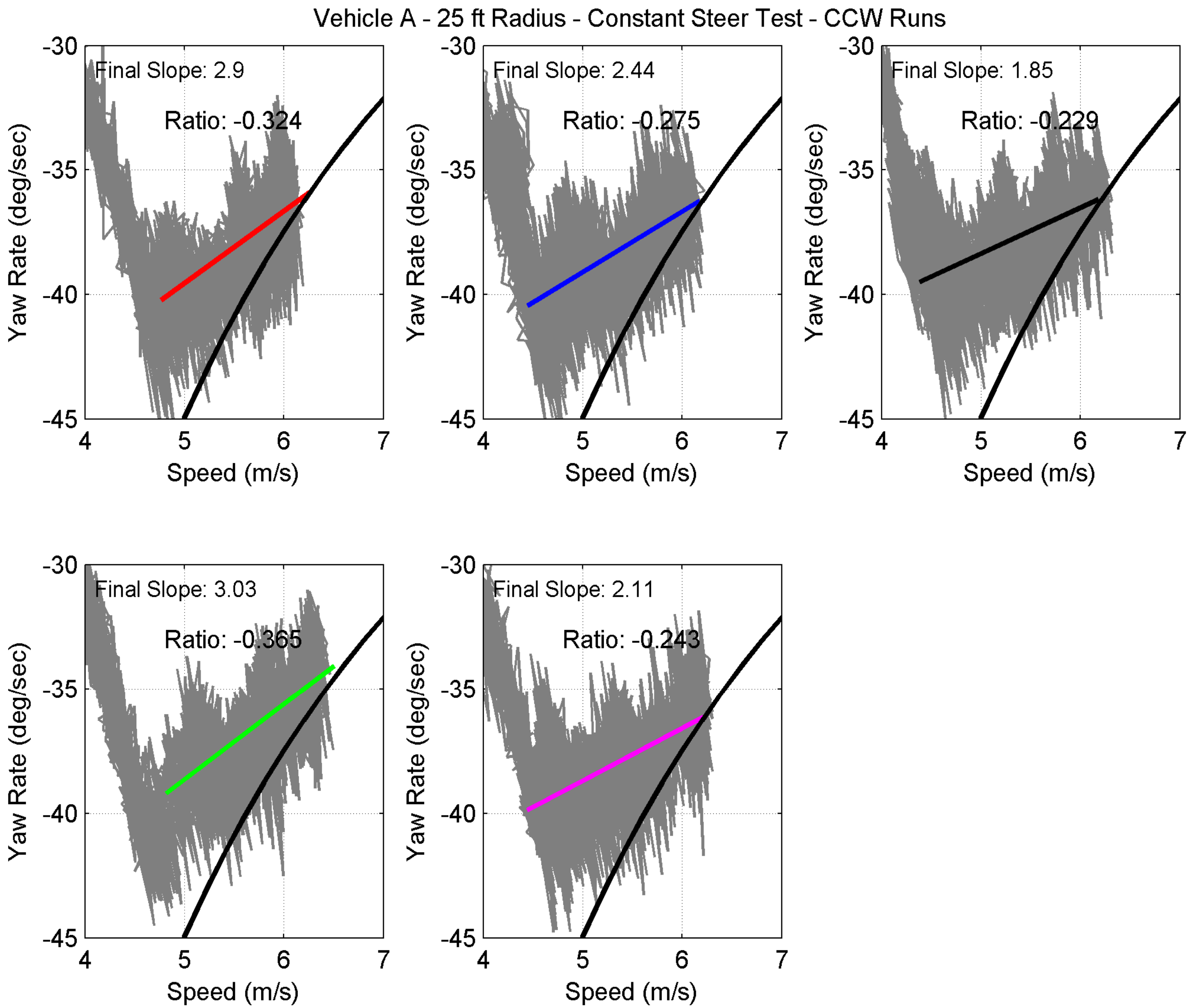
Vehicle A
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

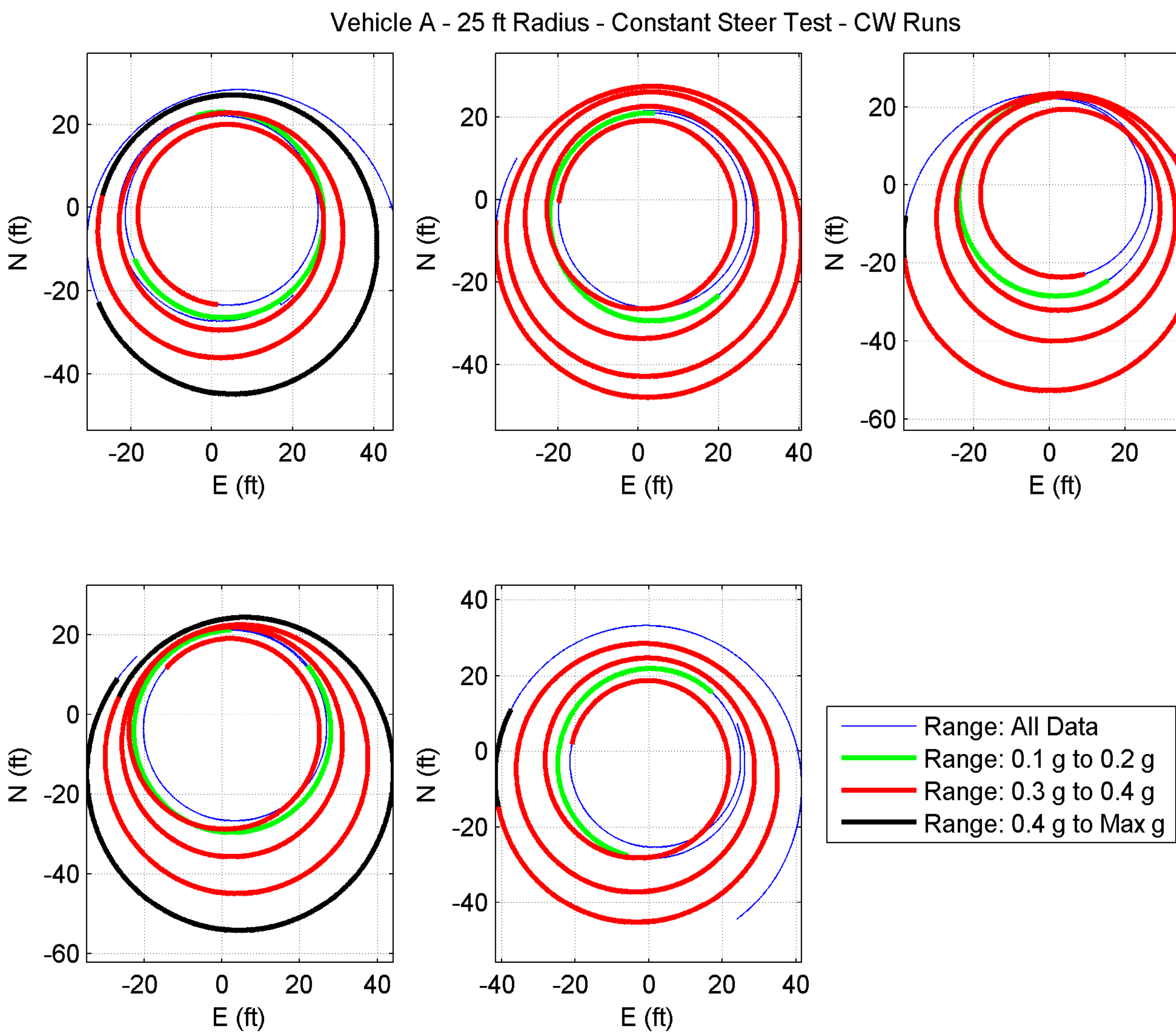

Vehicle A - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7

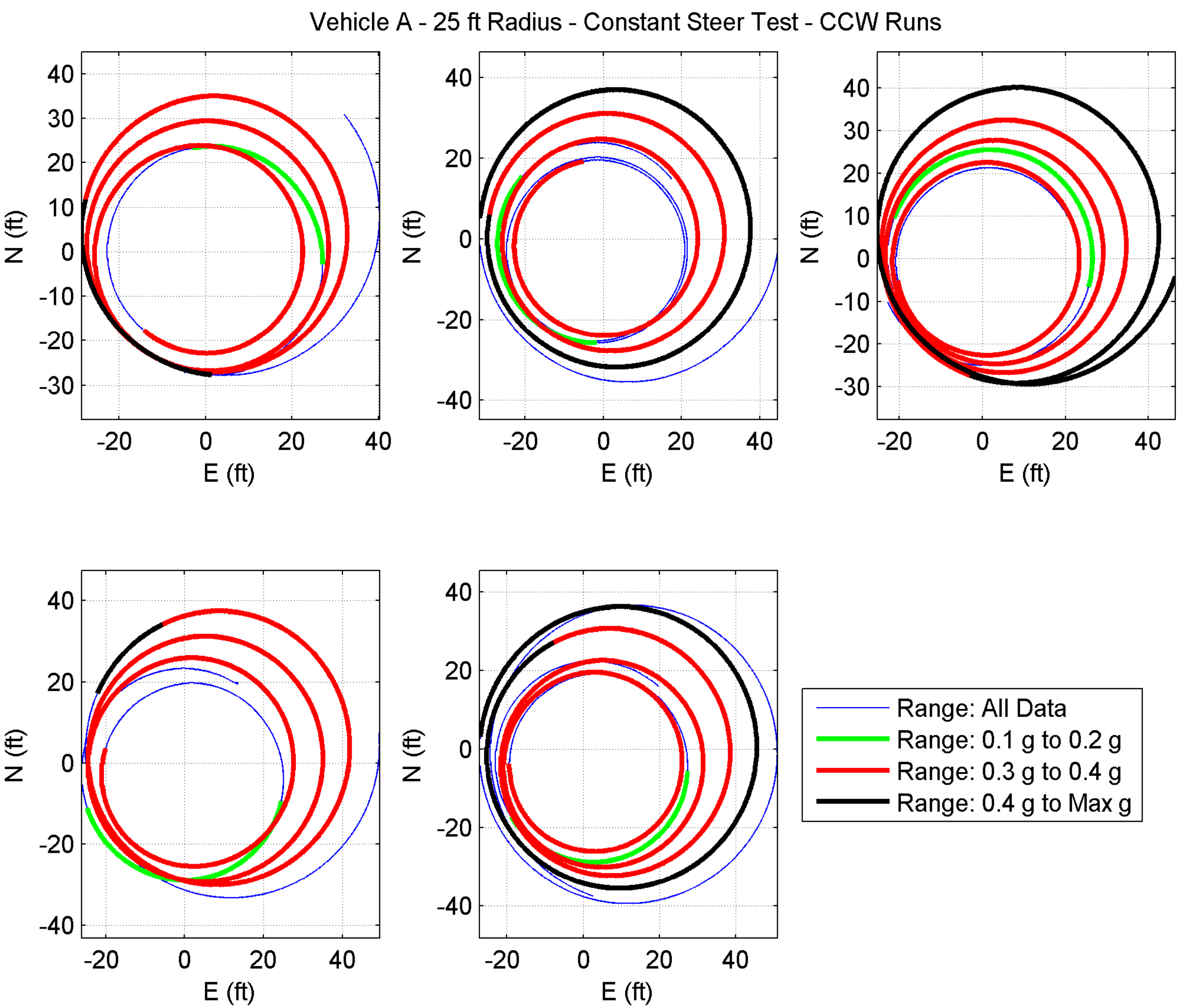

Vehicle A - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 8.13 7.76 7.85 7.92 8.78 STD=0.411
CW Final Slopes: -2.74 -3.45 -3.61 -3.07 -3.59 STD=0.375
CW Ratios: -0.337 -0.444 -0.46 -0.388 -0.408 STD=0.0487
CW Average: 0.407
Average Ratio: 0.347
CCW Average: 0.287
CCW Ratios: -0.324 -0.275 -0.229 -0.365 -0.243 STD=0.0569
CCW Final Slopes: 2.9 2.44 1.85 3.03 2.11 STD=0.504
CCW Initial Slopes: -8.94 -8.87 -8.07 -8.3 -8.68 STD=0.374
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5

Vehicle A - 25 ft Radius - Constant Steer Test - CW Runs

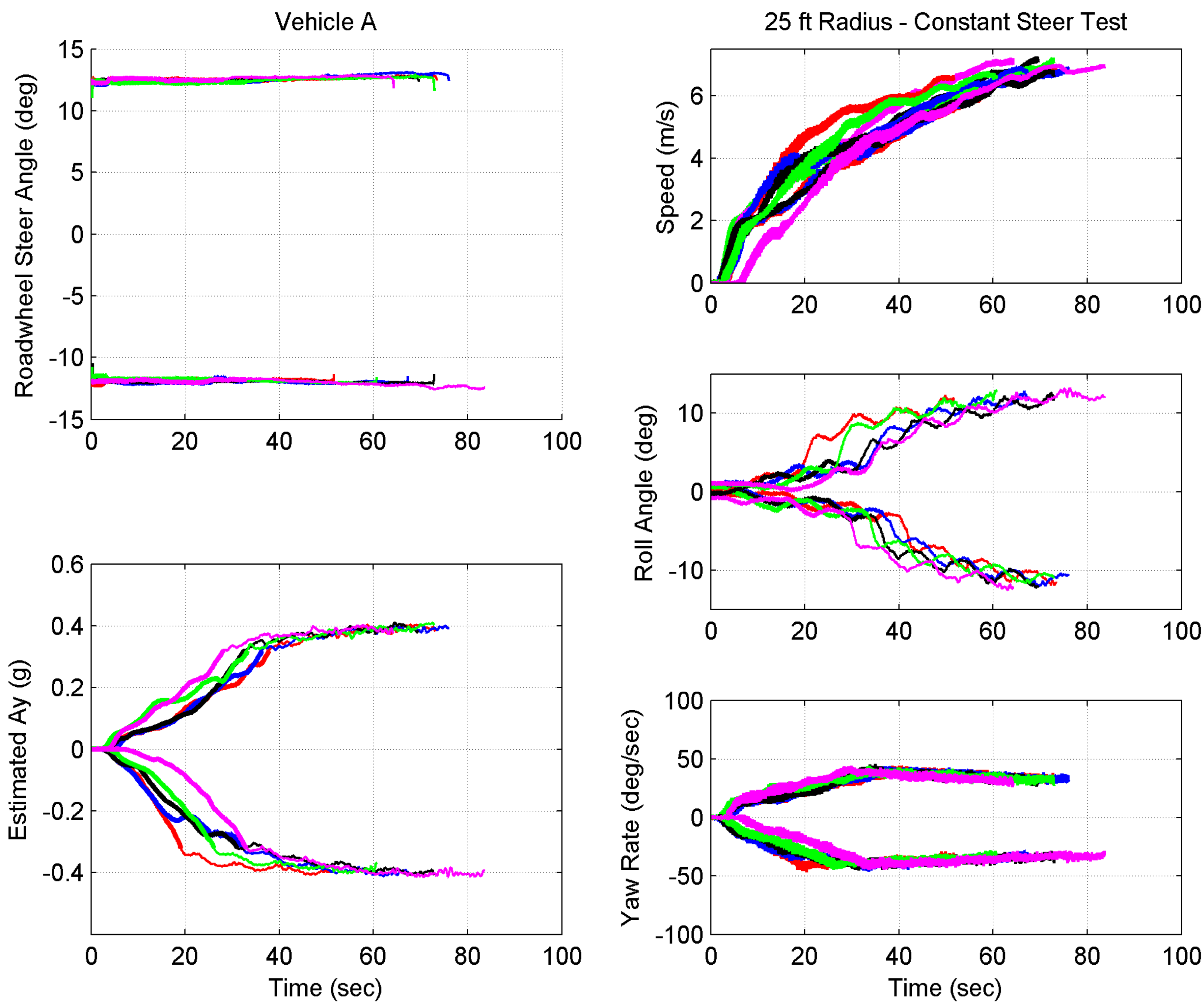



Vehicle A - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 2.9
Ratio: -0.324
Final Slope: 2.44
Ratio: -0.275
Final Slope: 1.85
Ratio: -0.229
Final Slope: 3.03
Ratio: -0.365
Final Slope: 2.11
Ratio: -0.243
Yaw Rate (deg/sec)
Speed (m/s)

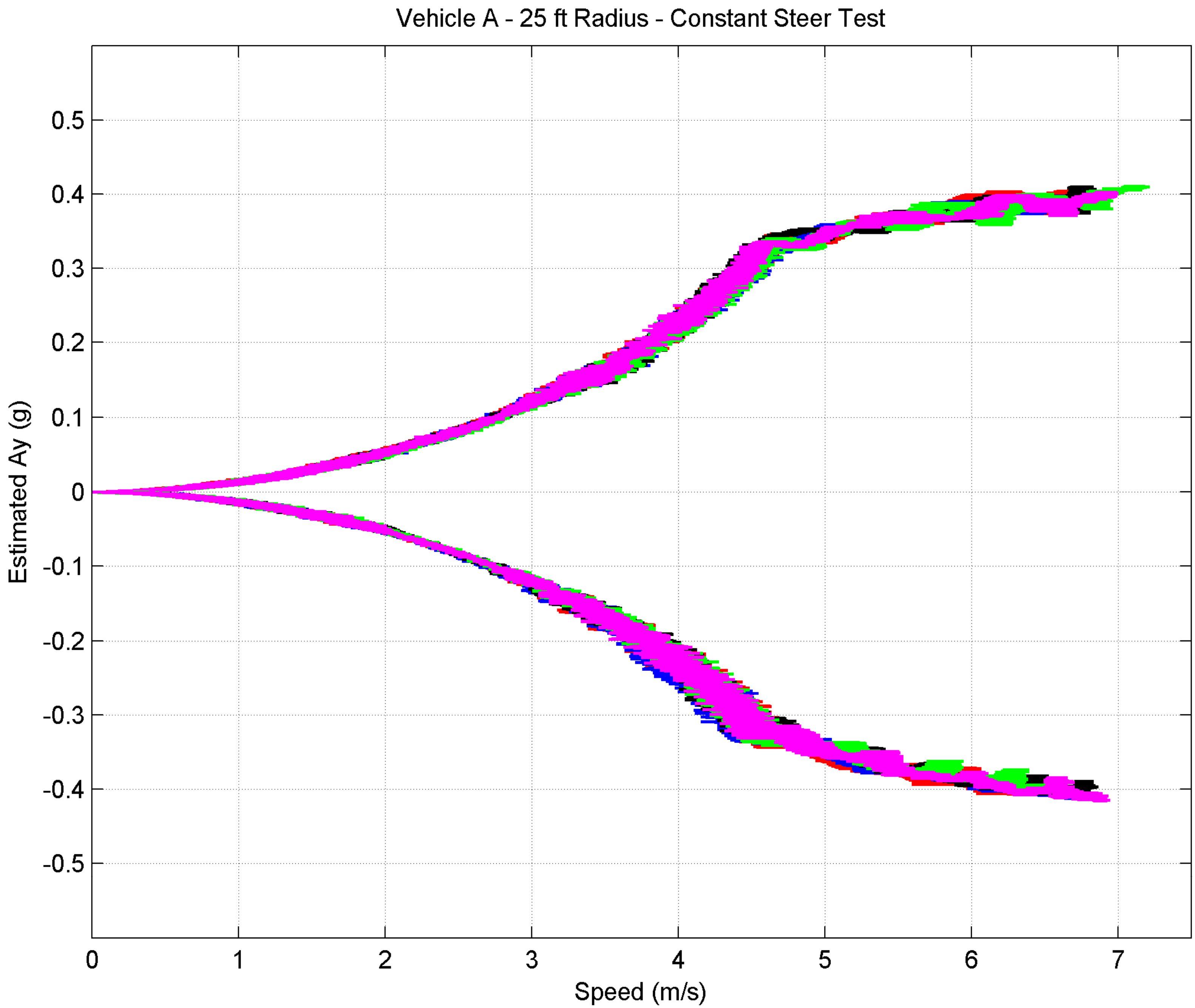

Vehicle A - 25 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

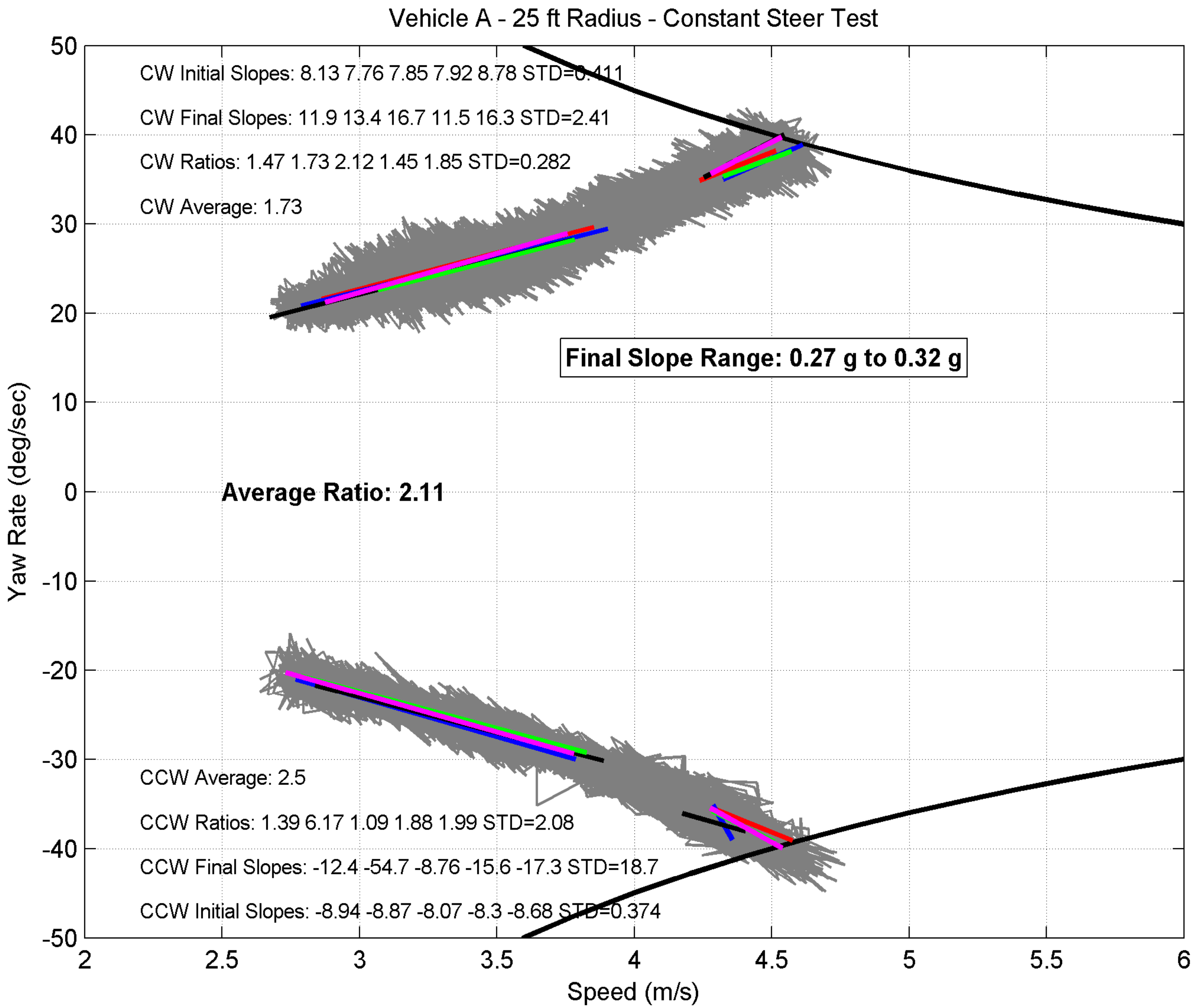


Vehicle A - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
40
30
20
10
0
-10
-20
-30
-40
-20
0
20
40
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

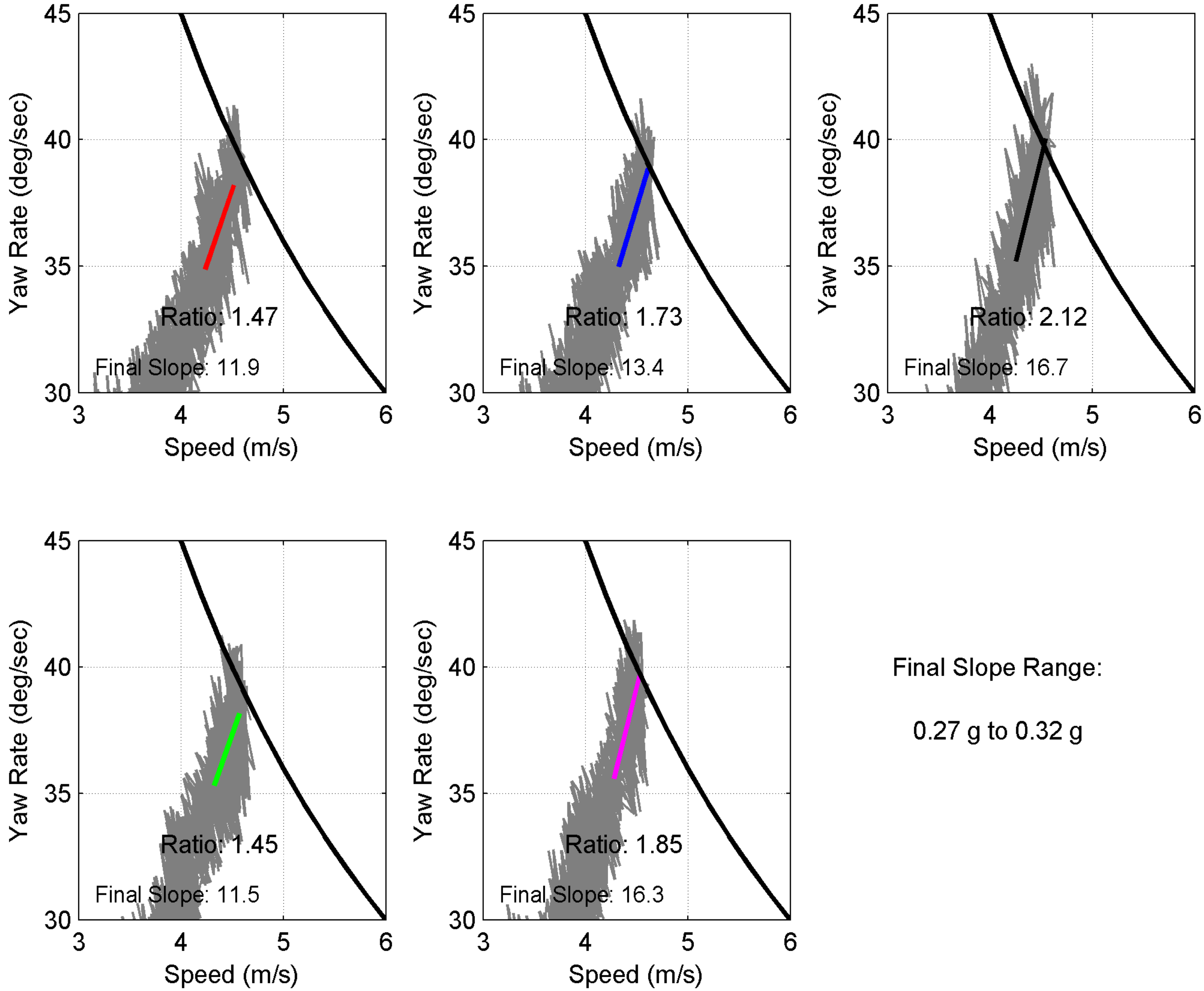


Vehicle A
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
20
40
60
80
100
Speed (m/s)
6
4
2
0
0
20
40
60
80
100
Roll Angle (deg)
10
0
-10
0
20
40
60
80
100
Estimated Ay (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
20
40
60
80
100
Time (sec)
Yaw Rate (deg/sec)
100
50
0
-50
-100
0
20
40
60
80
100
Time (sec)


Vehicle A - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
Speed (m/s)

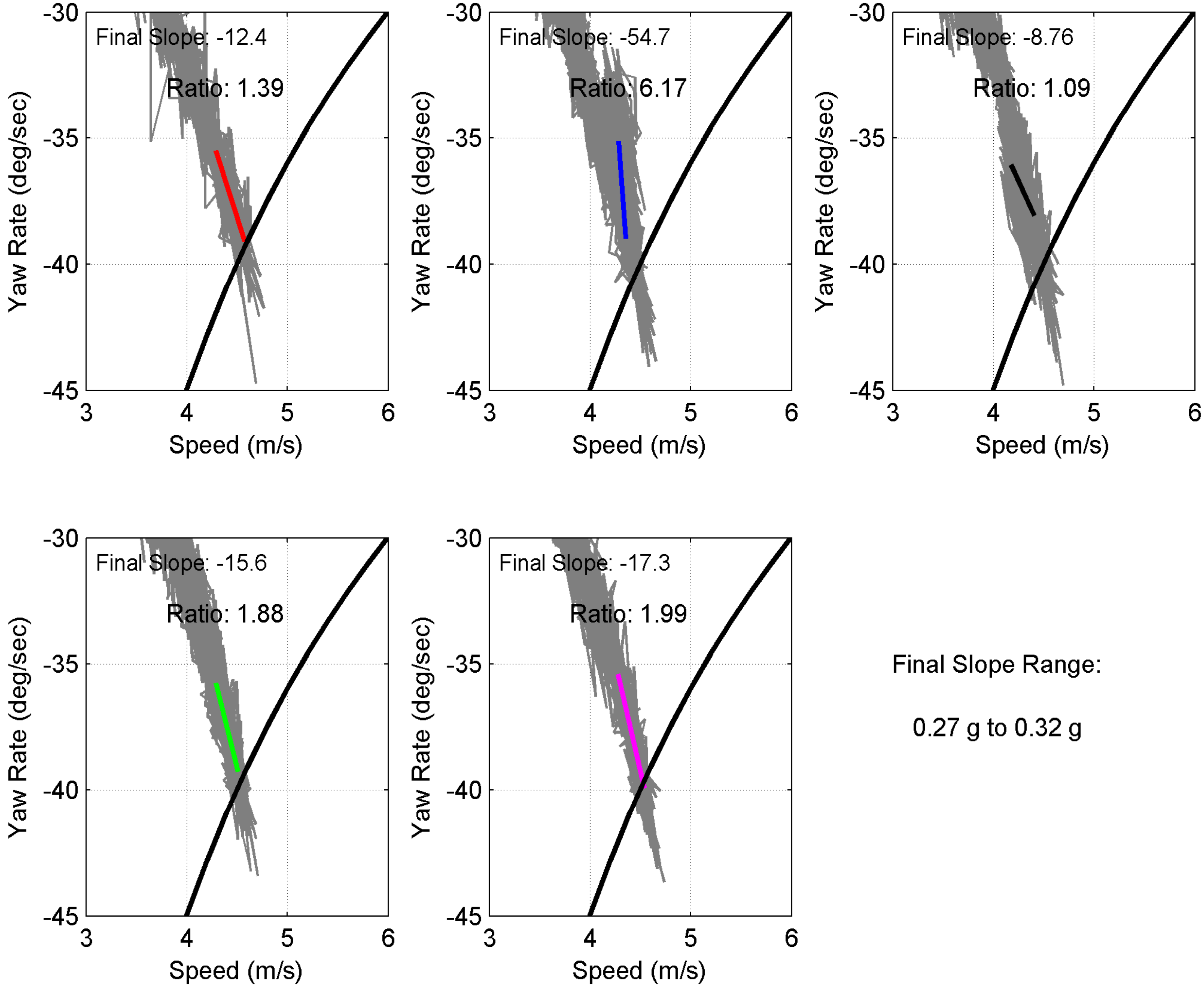


Vehicle A - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 8.13 7.76 7.85 7.92 8.78 STD=0.411
CW Final Slopes: 11.9 13.4 16.7 11.5 16.3 STD=2.41
CW Ratios: 1.47 1.73 2.12 1.45 1.85 STD=0.282
CW Average: 1.73
Final Slope Range: 0.27 g to 0.32 g
Average Ratio: 2.11
CCW Average: 2.5
CCW Ratios: 1.39 6.17 1.09 1.88 1.99 STD=2.08
CCW Final Slopes: -12.4 -54.7 -8.76 -15.6 -17.3 STD=18.7
CCW Initial Slopes: -8.94 -8.87 -8.07 -8.3 -8.68 STD=0.374
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
2.5
3
3.5
4
4.5
5
5.5
6

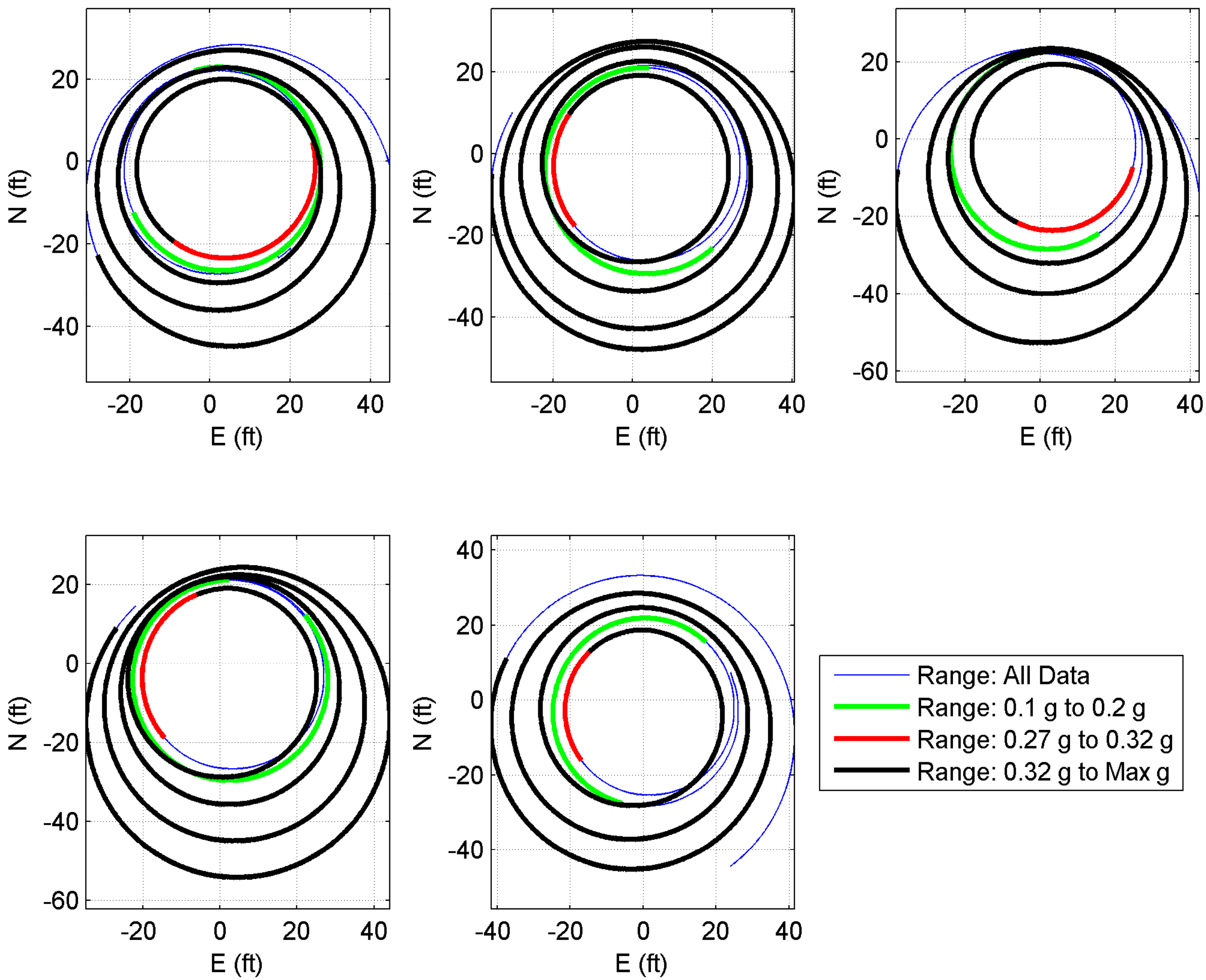


Final Slope Range:

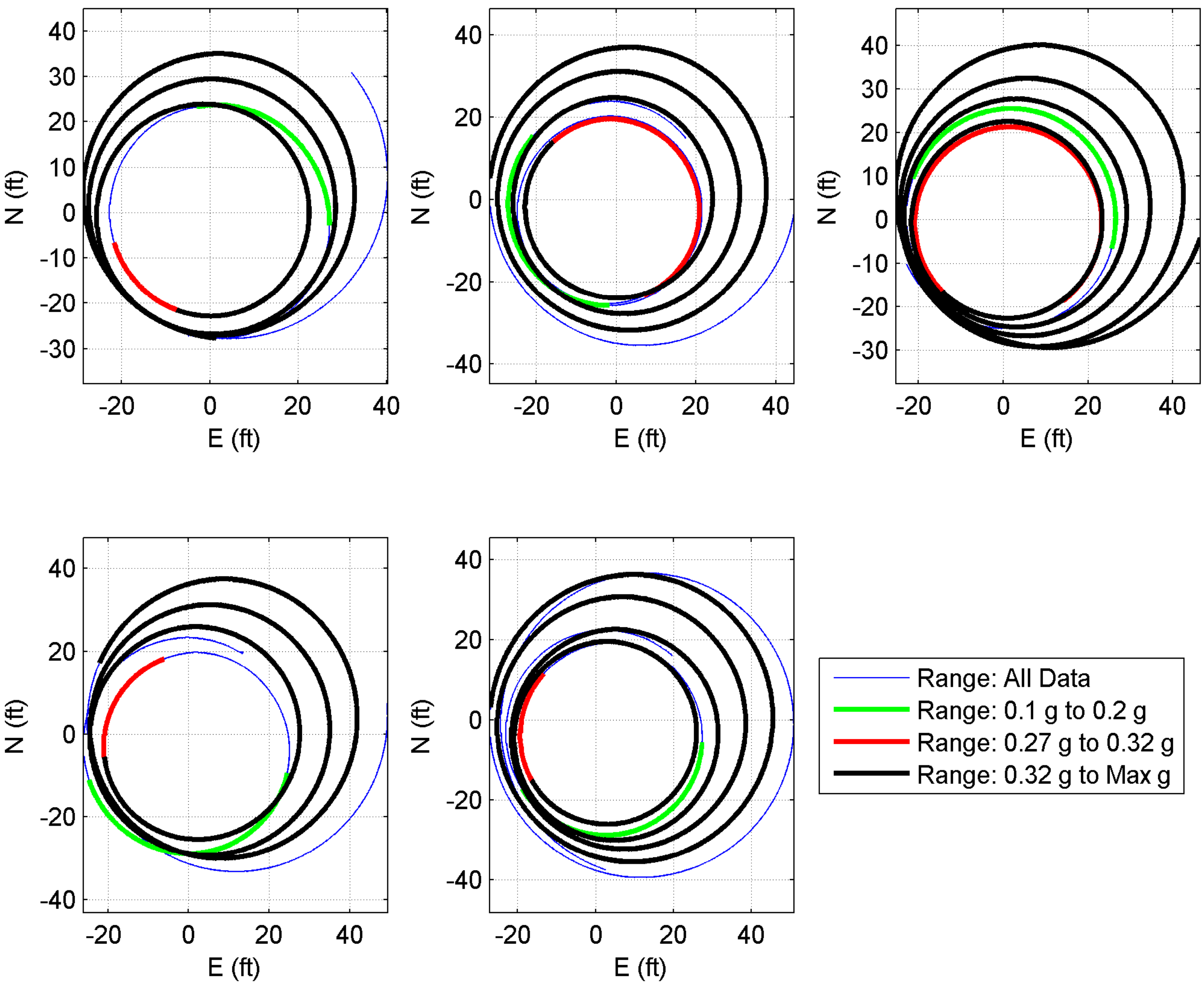
0.27 g to 0.32 g

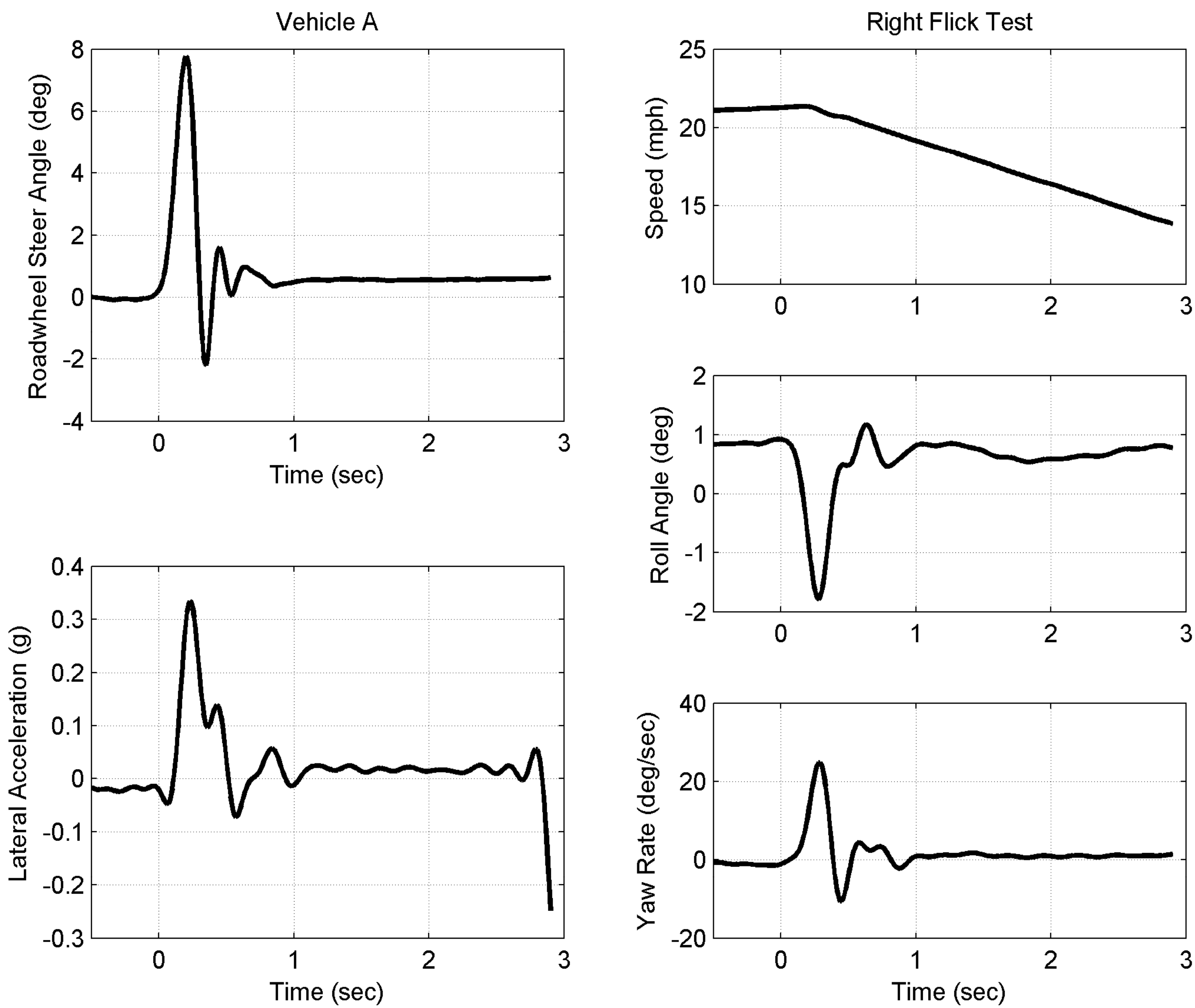

Final Slope: -12.4
Ratio: 1.39
Final Slope: -54.7
Ratio: 6.17
Final Slope: -8.76
Ratio: 1.09
Final Slope: -15.6
Ratio: 1.88
Final Slope: -17.3
Ratio: 1.99
Yaw Rate (deg/sec)
Speed (m/s)
-30
-35
-40
-45
3
4
5
6
Final Slope Range:
0.27 g to 0.32 g

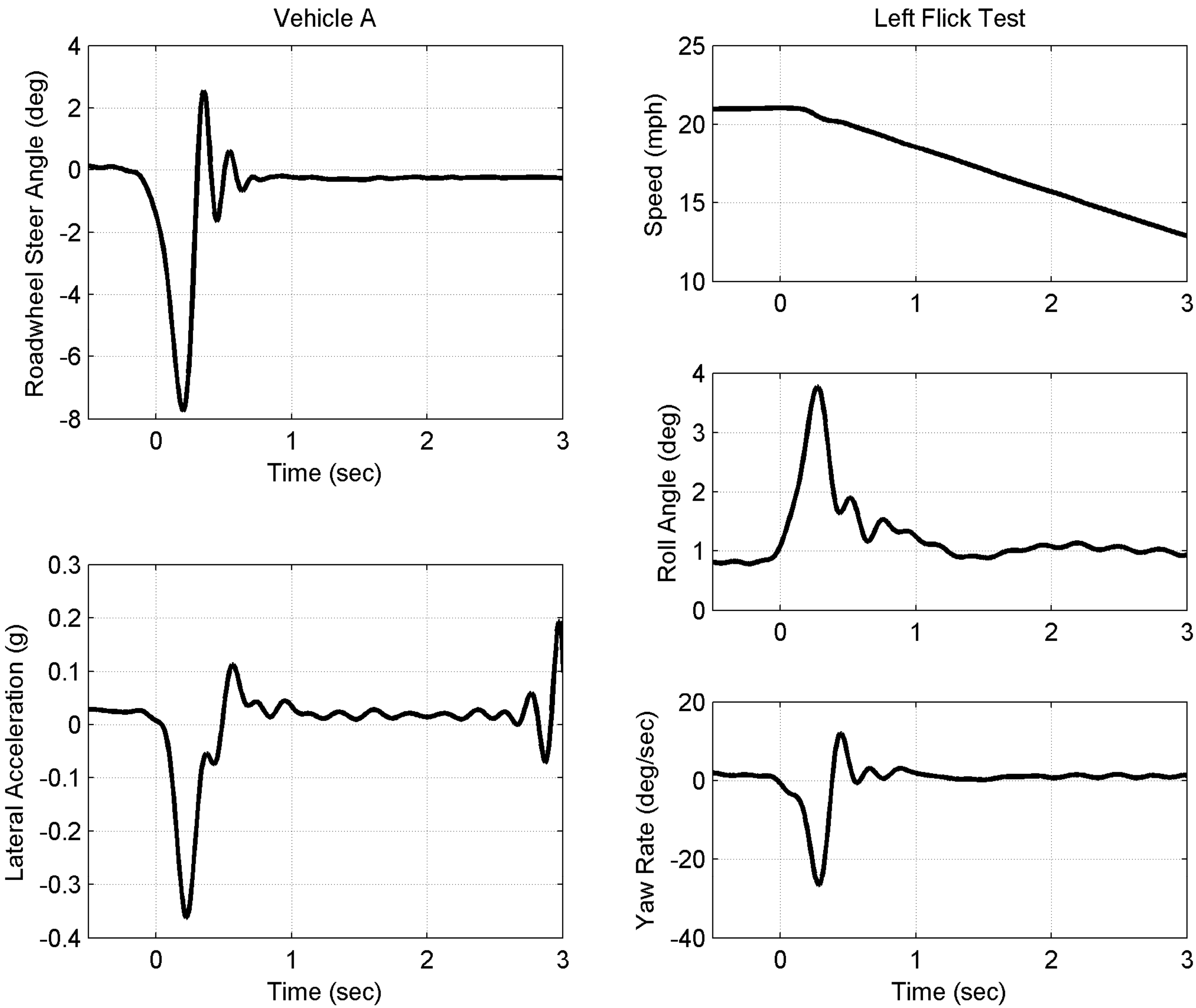
Vehicle A - 25 ft Radius - Constant Steer Test - CW Runs

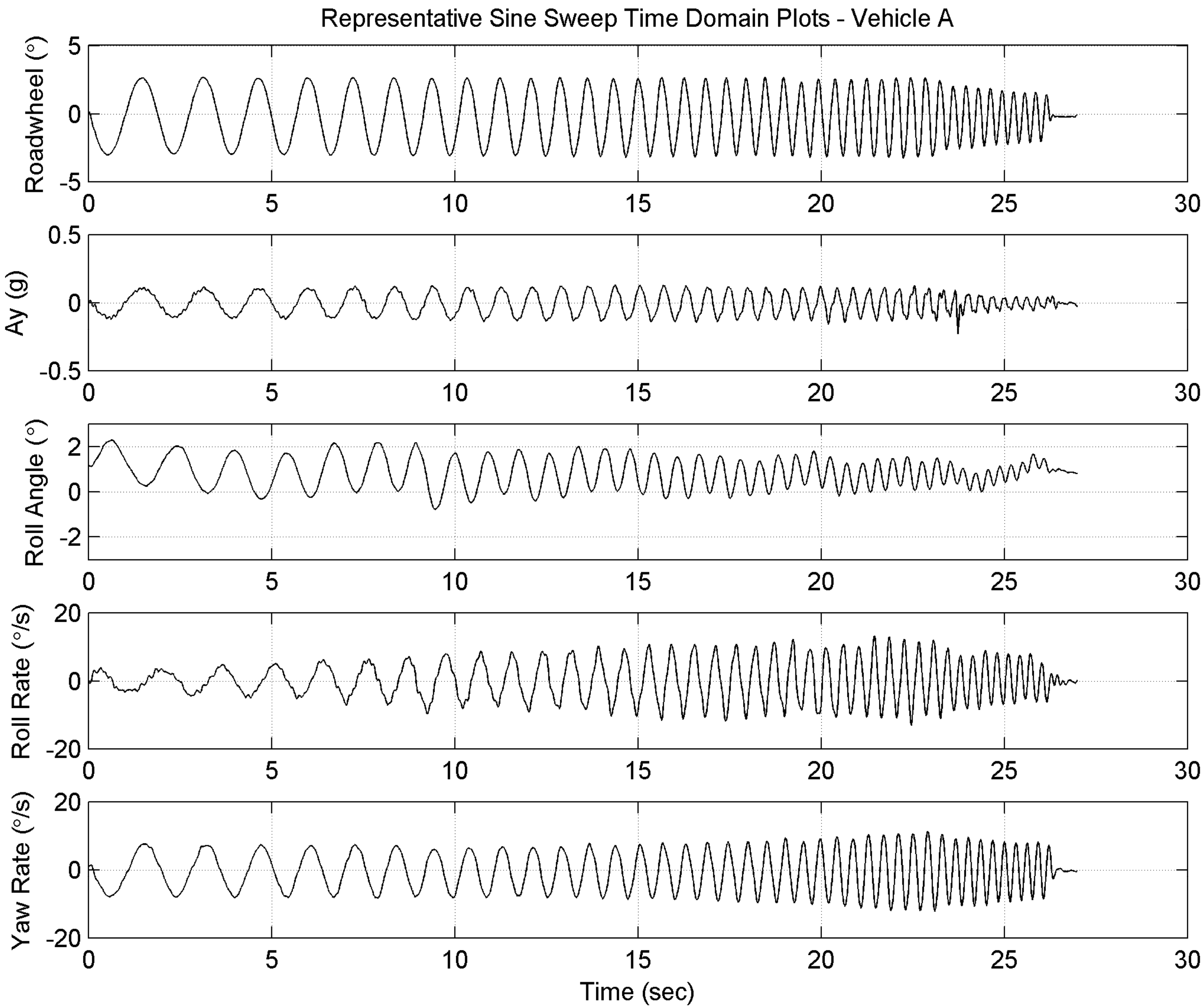


Vehicle A - 25 ft Radius - Constant Steer Test - CCW Runs

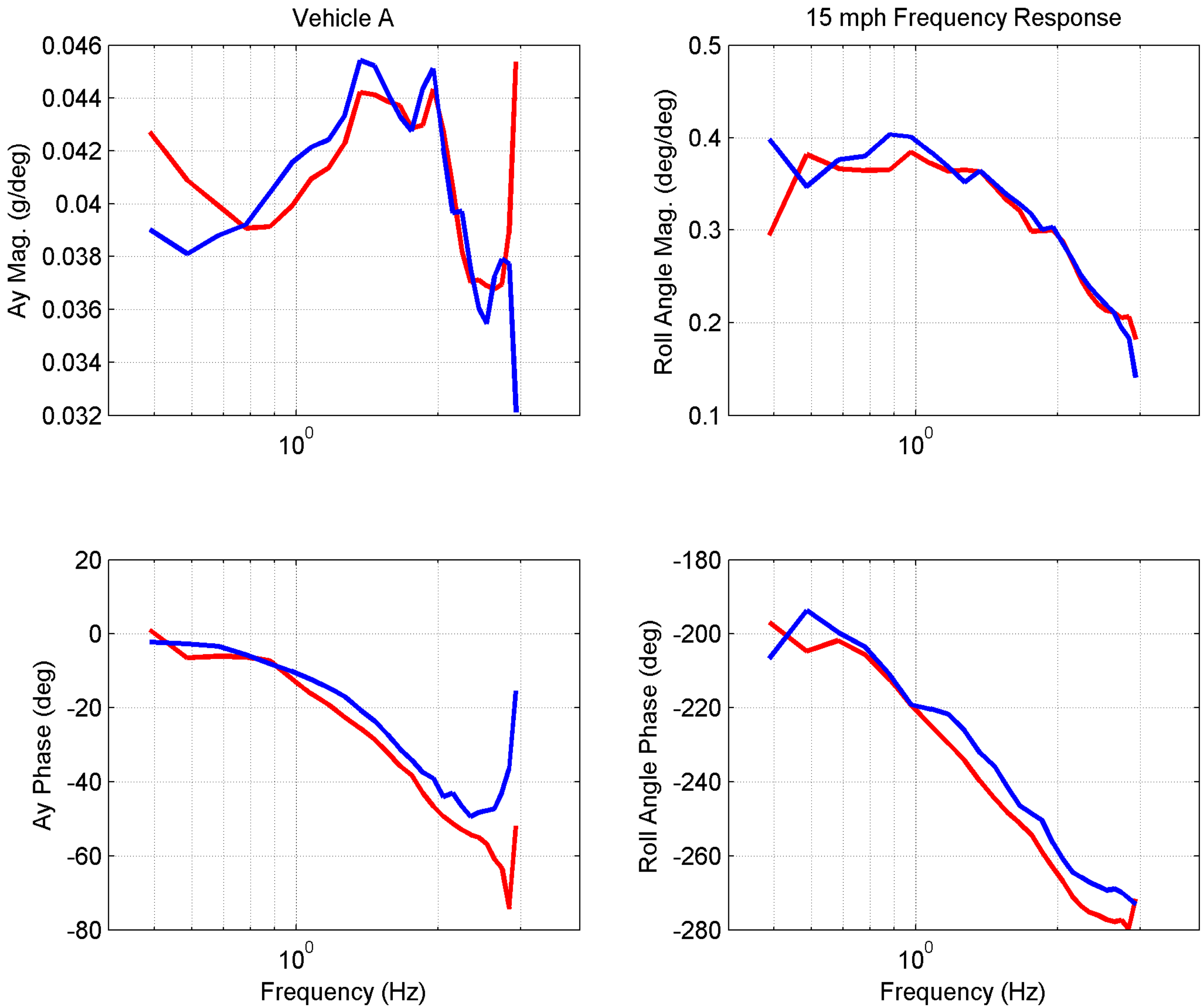



Vehicle A
Right Flick Test
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

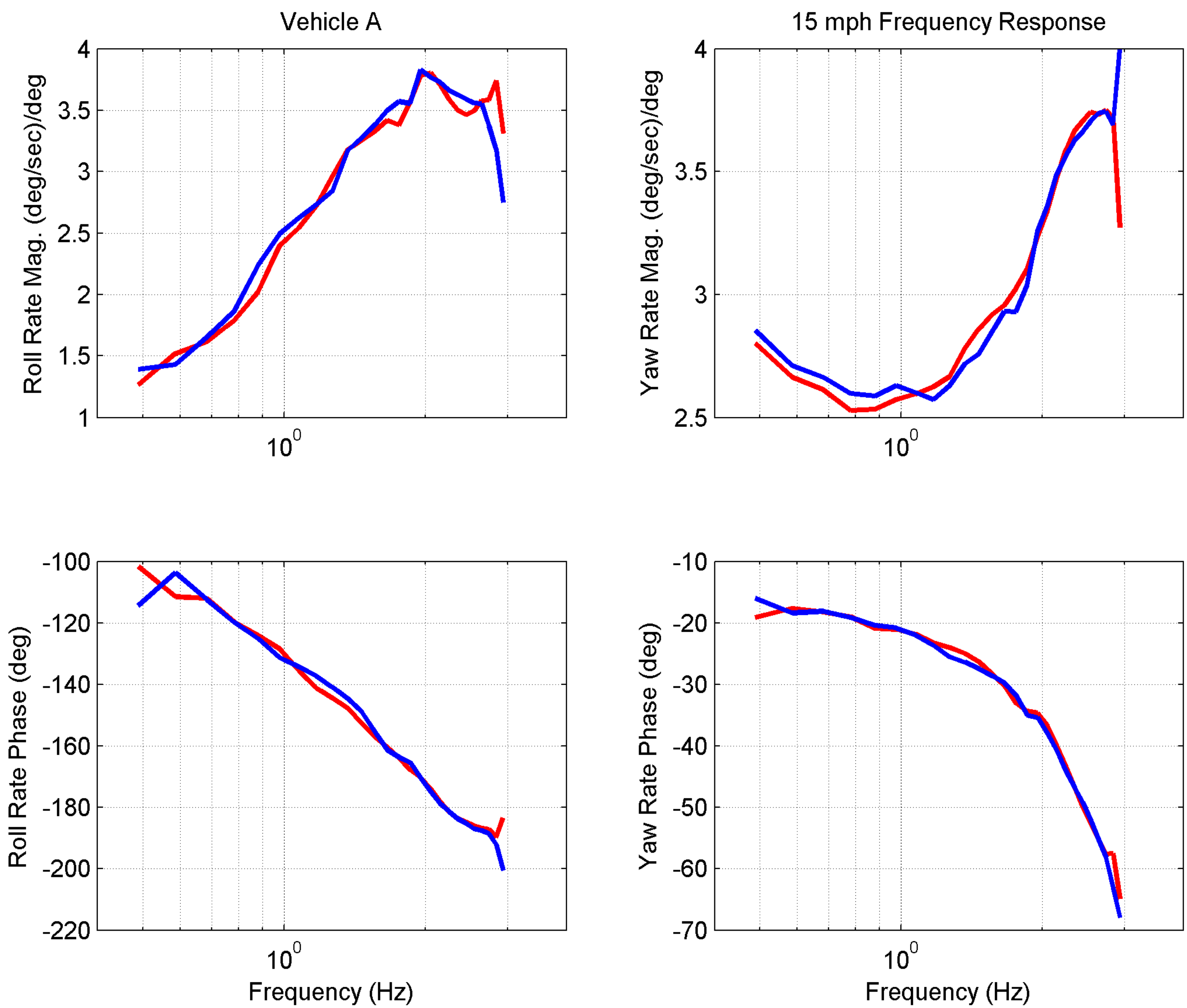

Vehicle A
Left Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

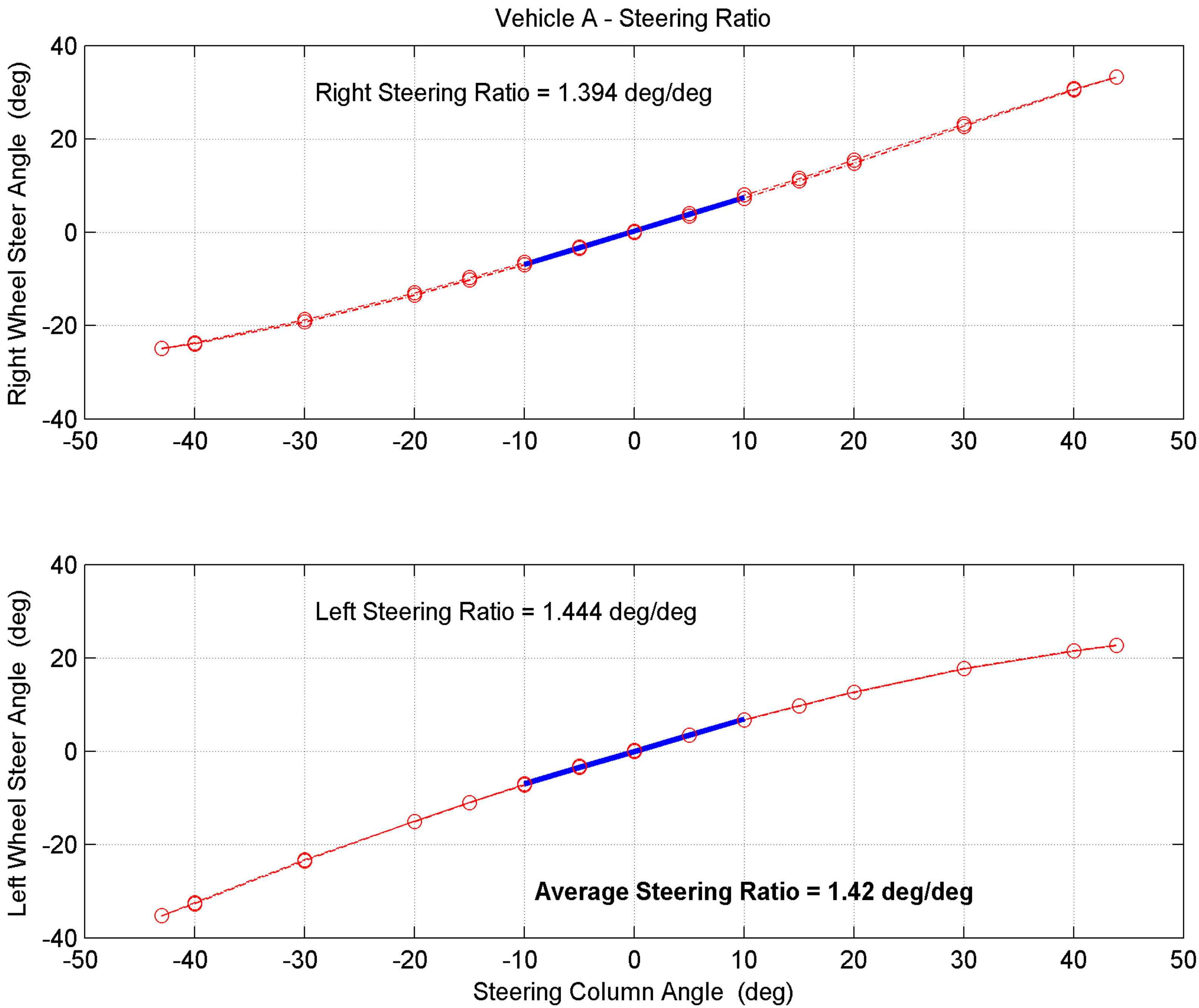


Representative Sine Sweep Time Domain Plots - Vehicle A
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

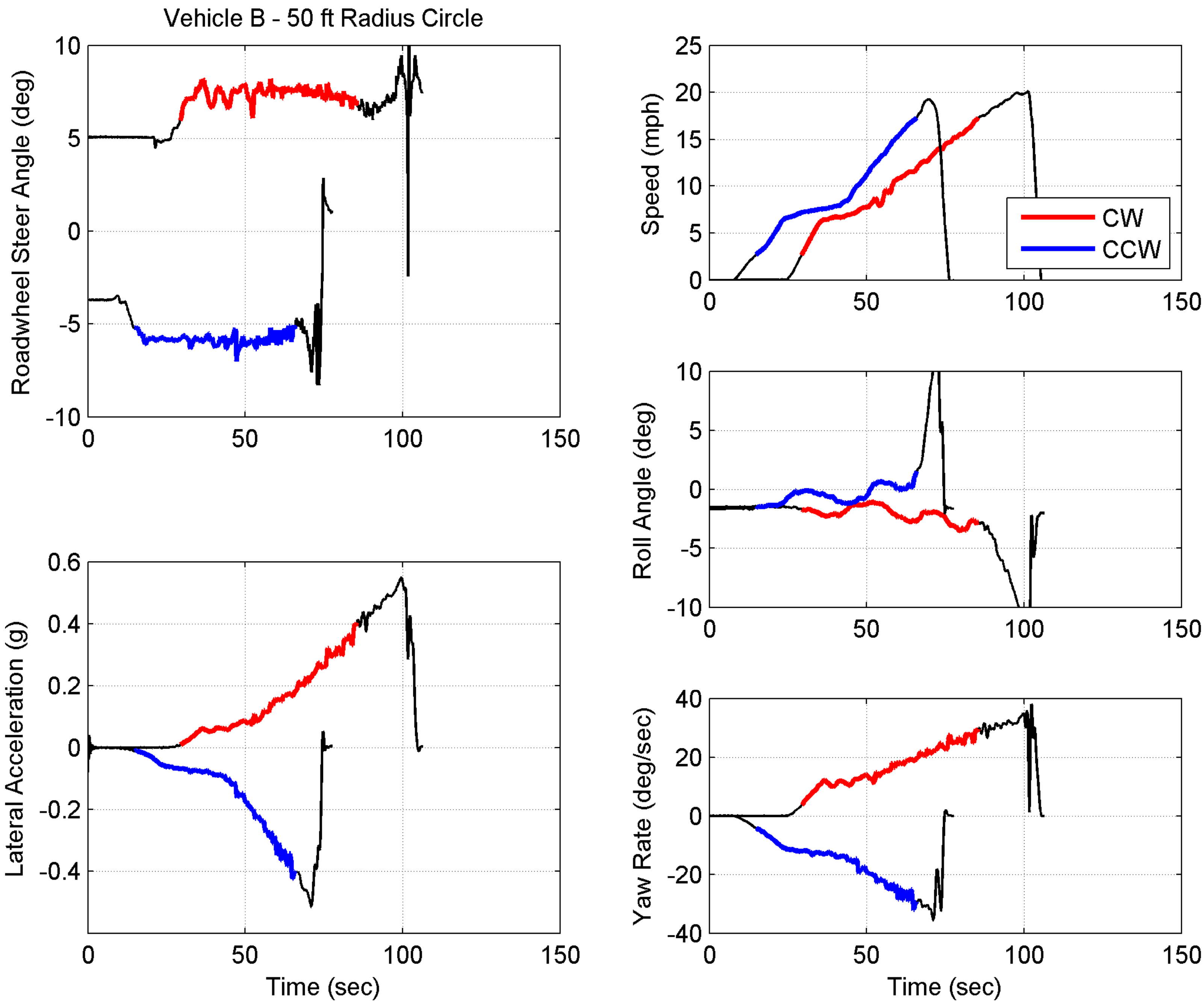


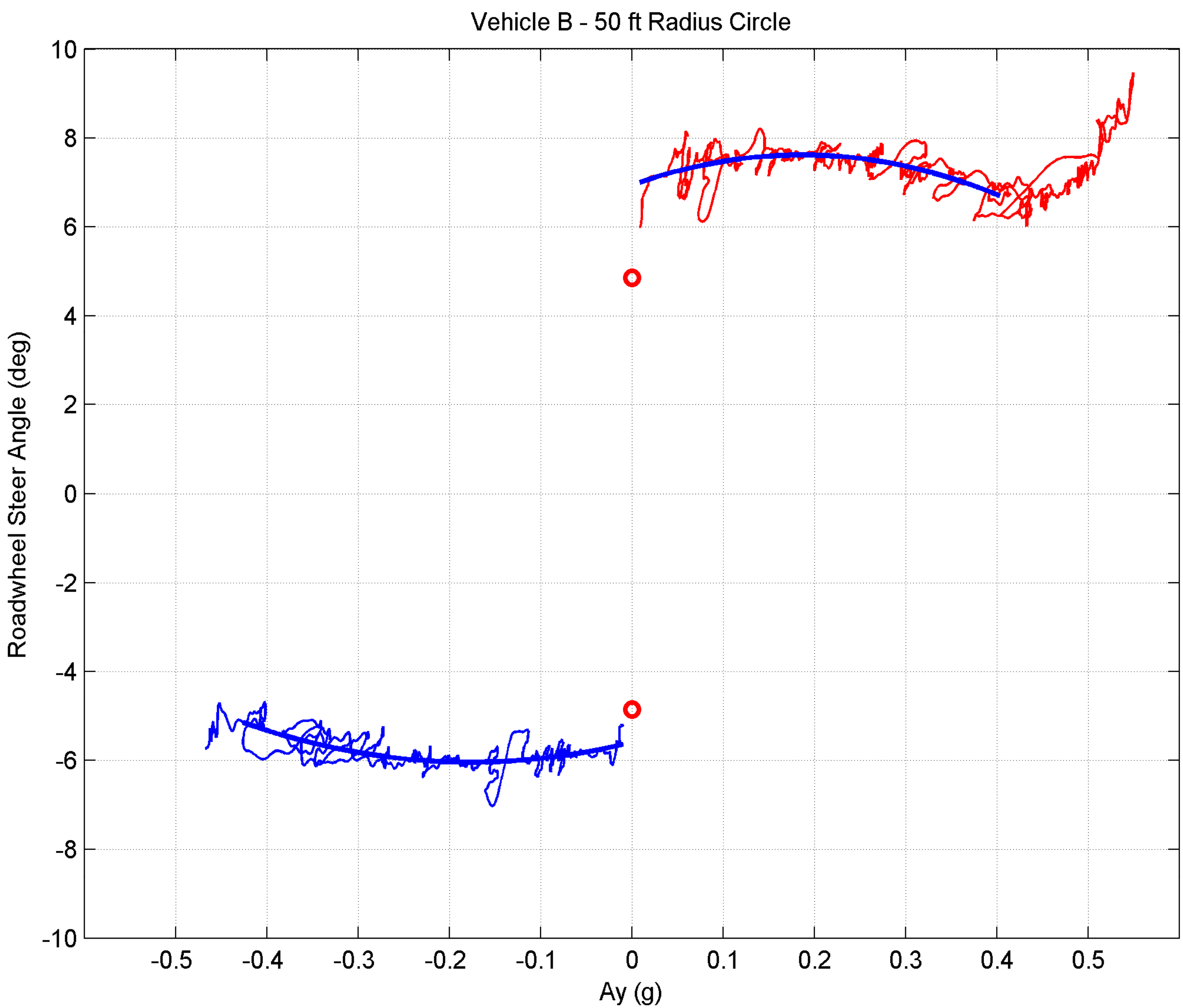
Vehicle A
15 mph Frequency Response
Ay Mag. (g/deg)
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
10^0
Roll Angle Mag. (deg/deg)
0.5
0.4
0.3
0.2
0.1
10^0
Ay Phase (deg)
20
0
-20
-40
-60
-80
10^0
Frequency (Hz)
Roll Angle Phase (deg)
-180
-200
-220
-240
-260
-280
10^0
Frequency (Hz)

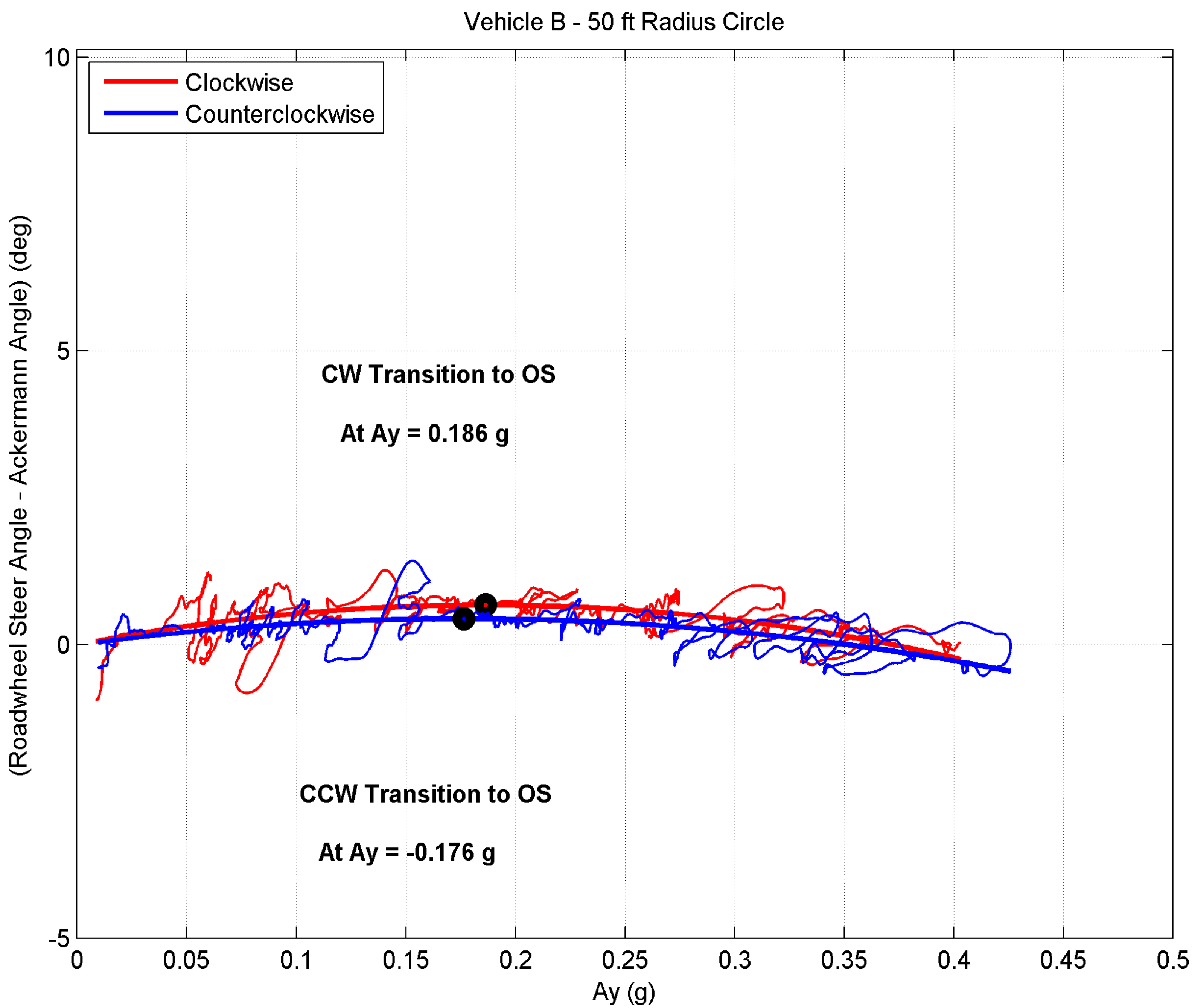

Vehicle A
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
4
3.5
3
2.5
2
1.5
1
2.5
-100
-120
-140
-160
-180
-200
-220
-10
-20
-30
-40
-50
-60
-70
10^0
Frequency (Hz)
Frequency (Hz)



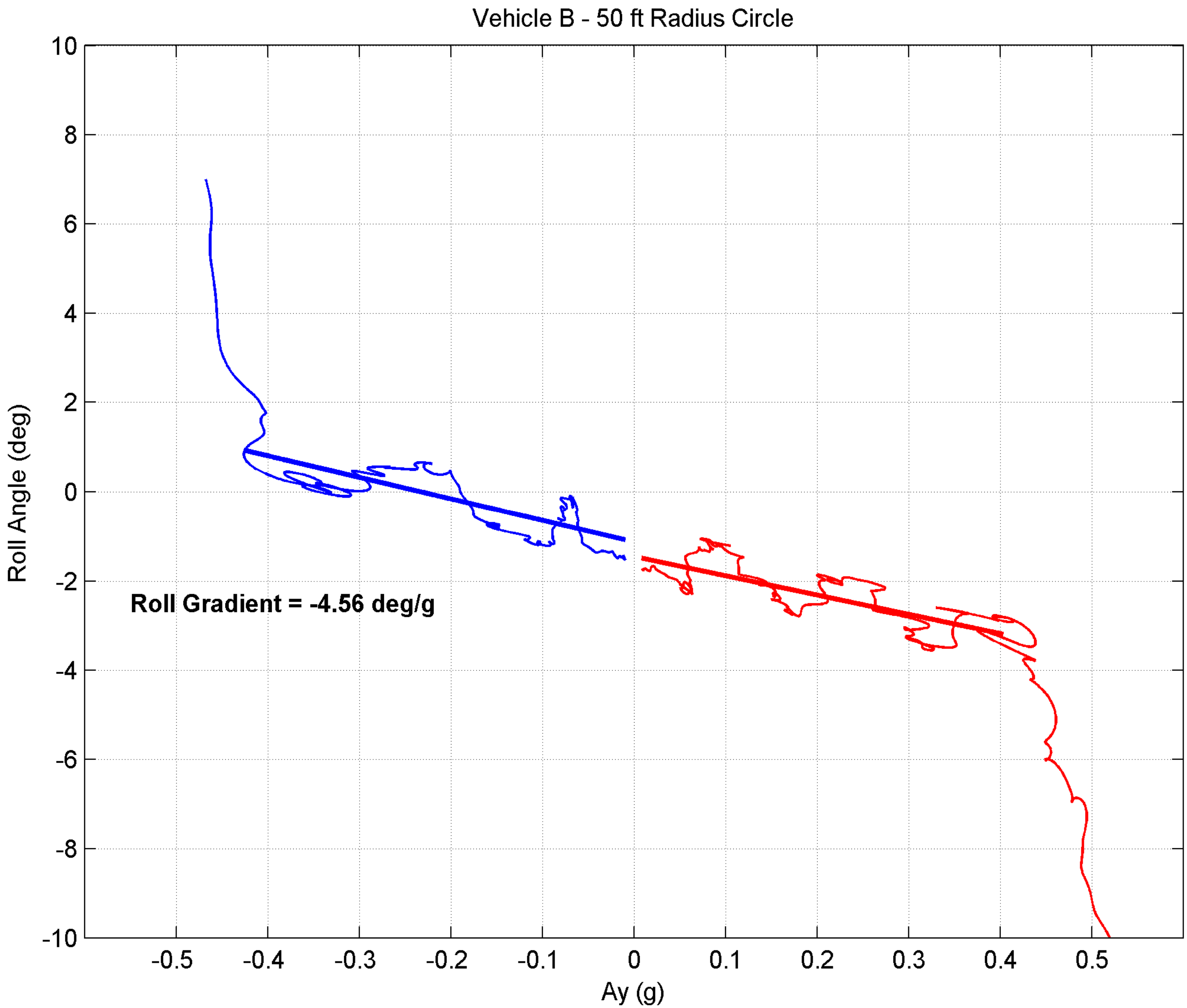
Vehicle A - Steering Ratio
Right Steering Ratio = 1.394 deg/deg
Right Wheel Steer Angle (deg)
Left Steering Ratio = 1.444 deg/deg
Left Wheel Steer Angle (deg)
Average Steering Ratio = 1.42 deg/deg
Steering Column Angle (deg)
40
20
0
-20
-40
-50
-40
-30
-20
-10
0
10
20
30
40
50

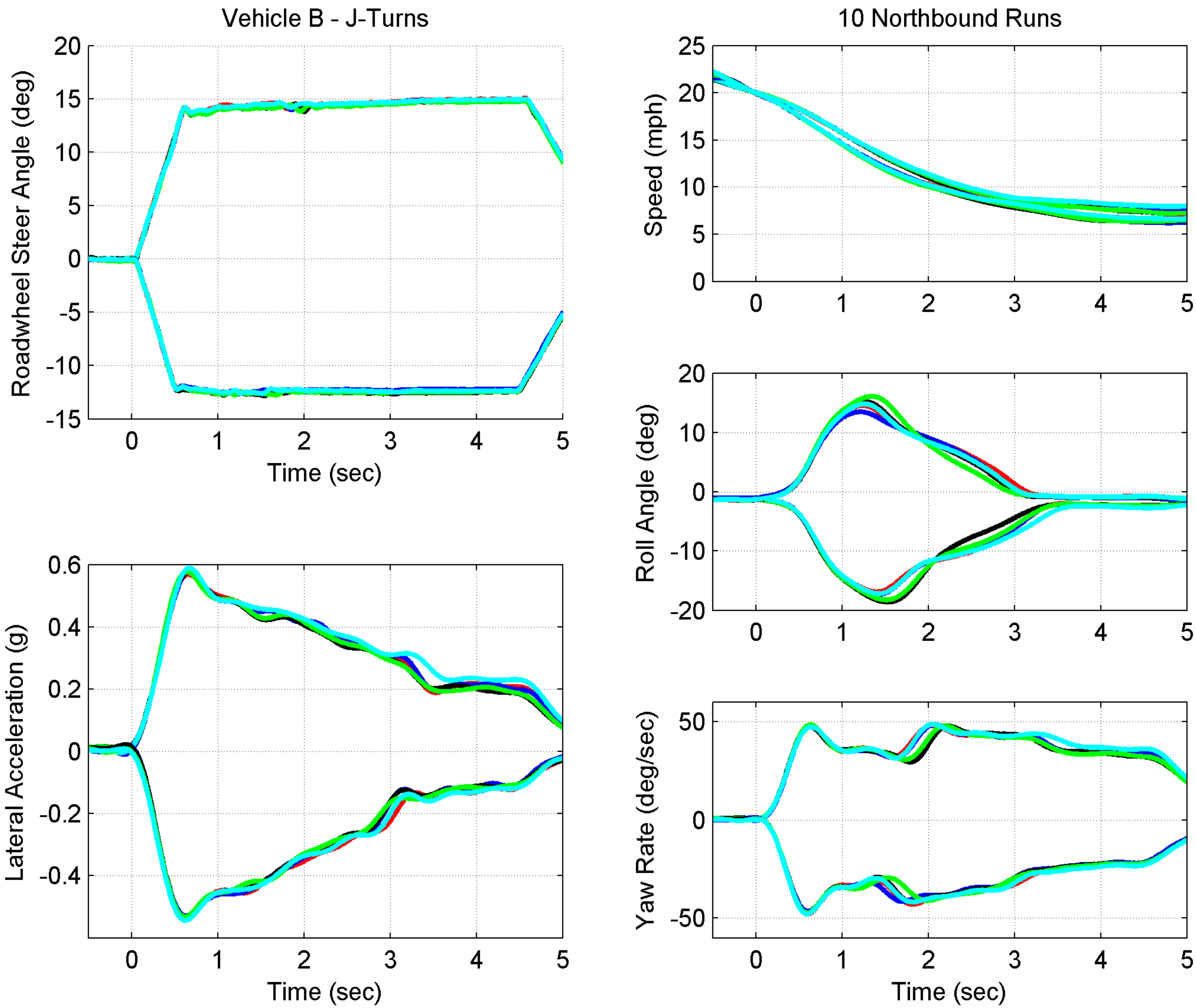

Vehicle B - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
CW
CCW
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

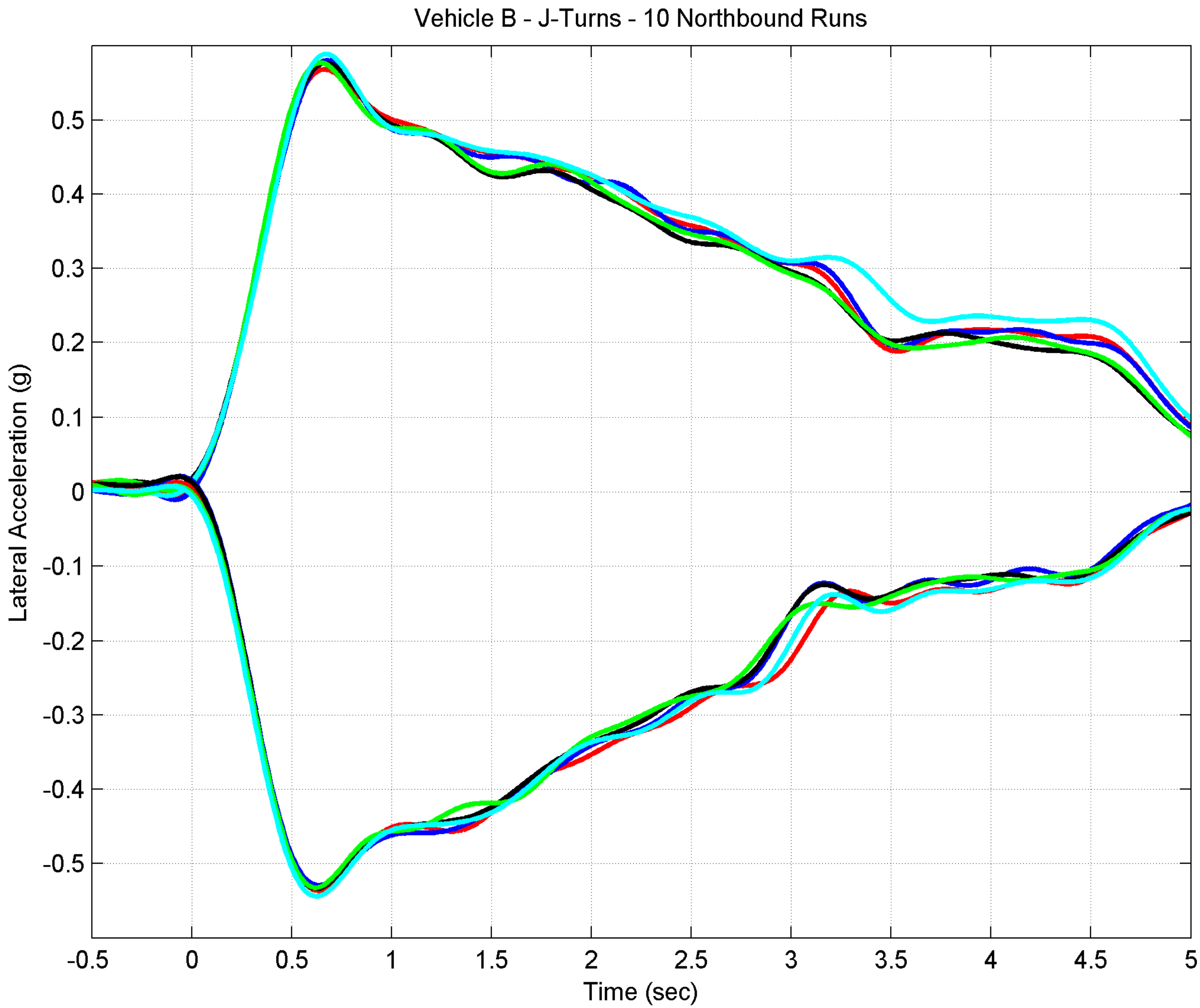

Vehicle B - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

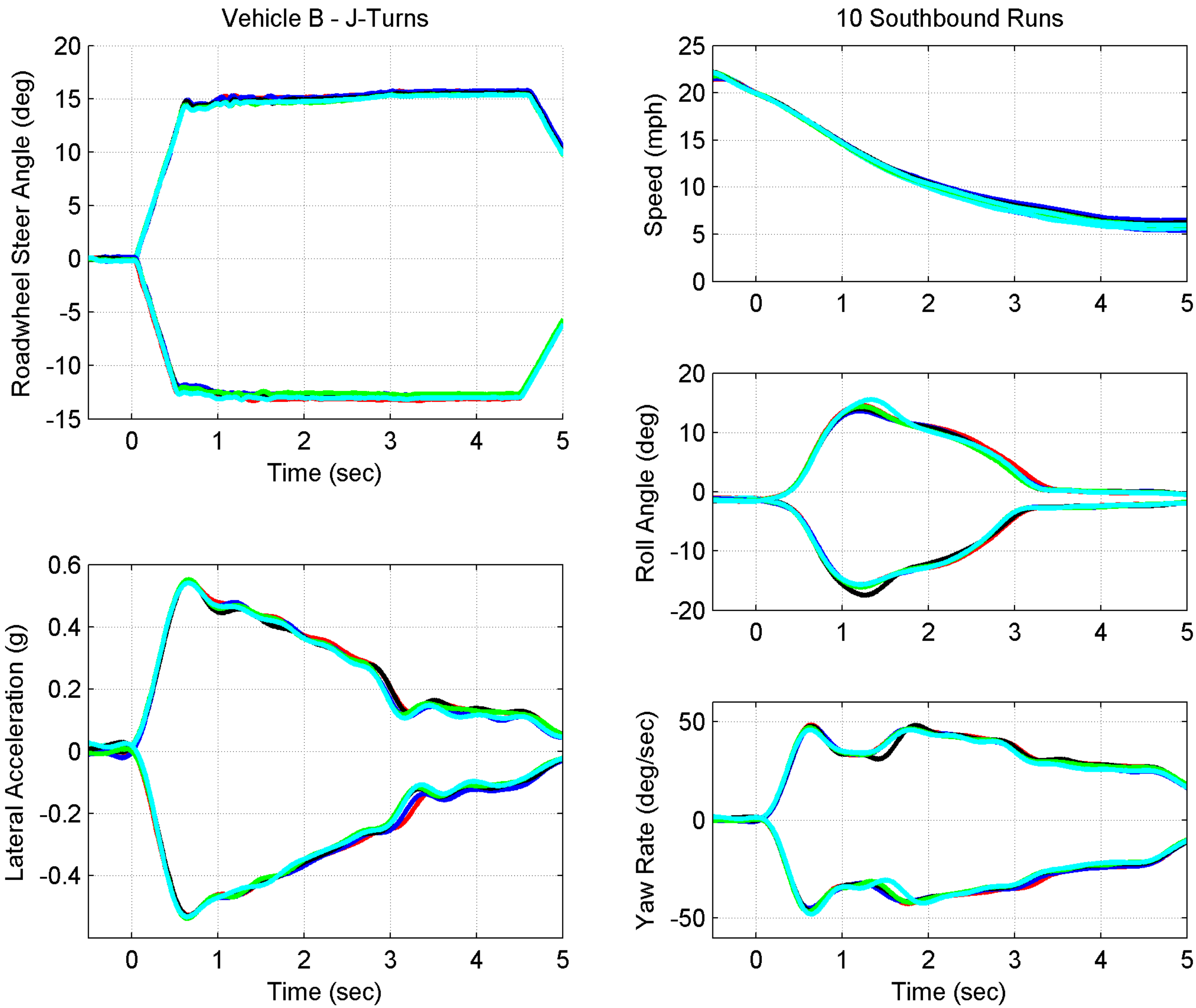


Vehicle B - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.186 g
CCW Transition to OS
At Ay = -0.176 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5


Vehicle B - 50 ft Radius Circle
Roll Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)
Roll Gradient = -4.56 deg/g

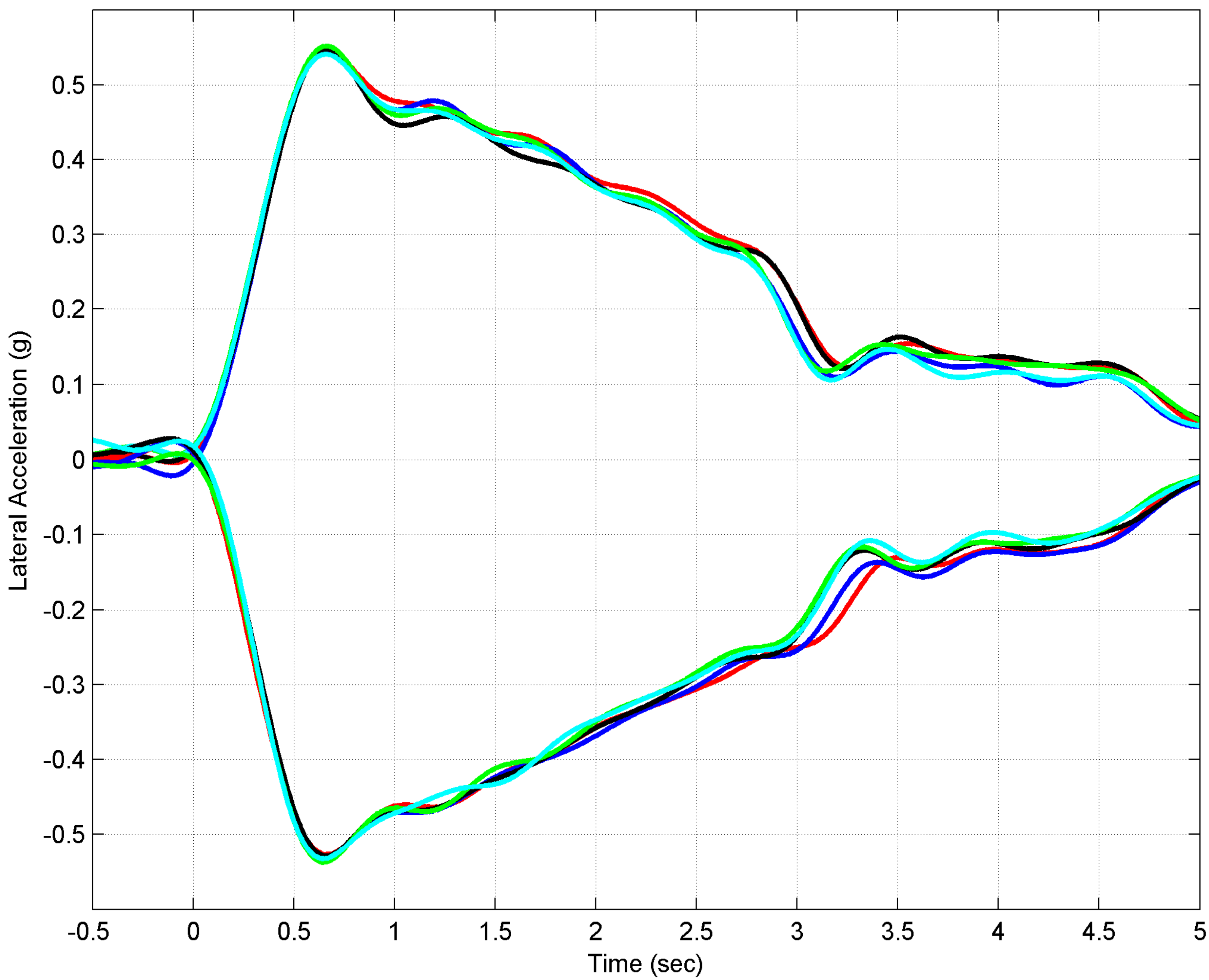

Vehicle B - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle B - J-Turns - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle B - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

Vehicle B - J-Turns - 10 Southbound Runs



Vehicle B

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

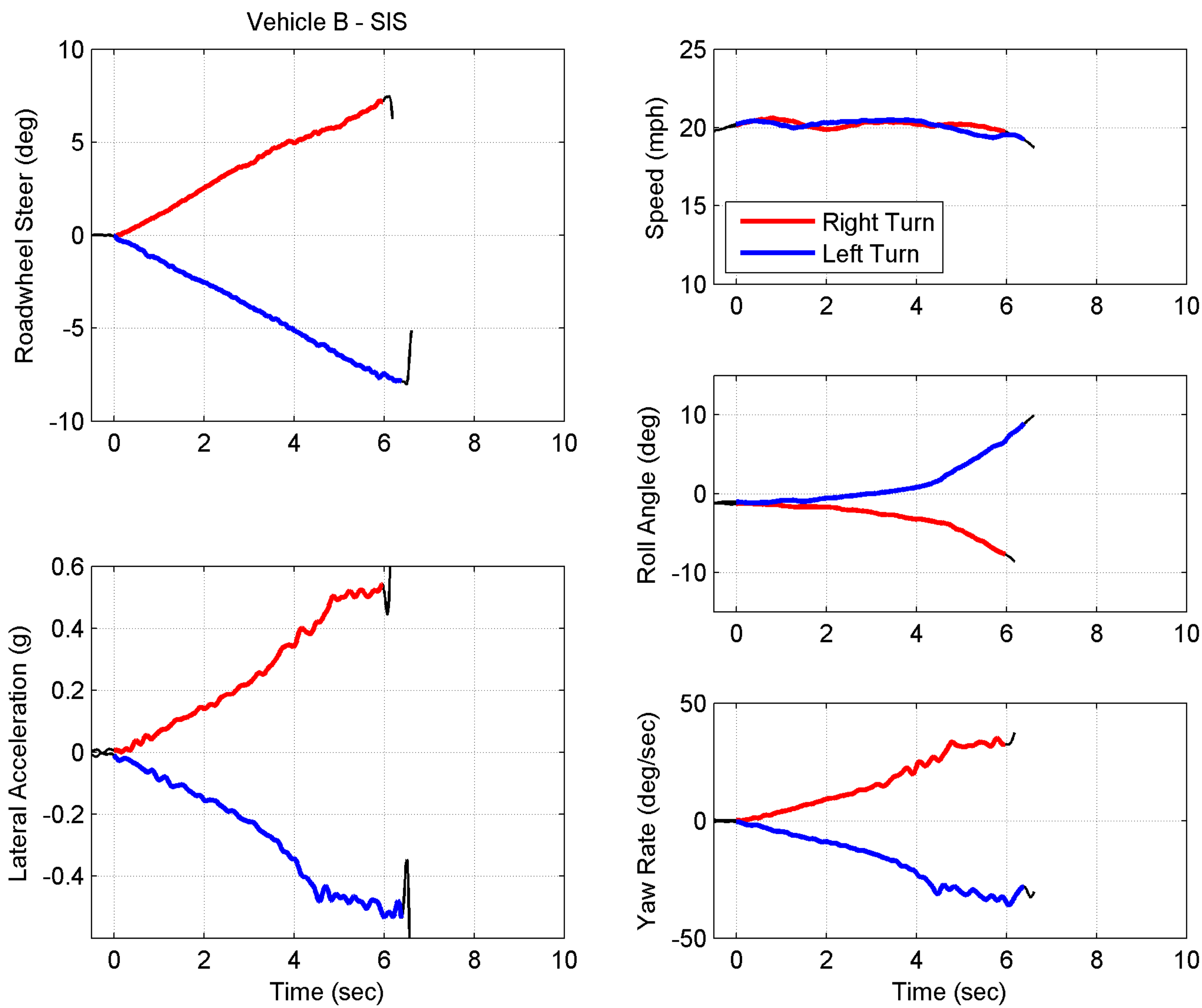
Run Number	Northbound Right Turns	Northbound Left Turns	Average of 10 Northbound Runs
1	0.5679	-0.5370	
2	0.5801	-0.5298	
3	0.5766	-0.5341	
4	0.5770	-0.5330	
5	0.5885	-0.5444	
Mean Value of 5 Runs	0.5780	-0.5357	**0.5568**
Standard Deviation of 5 Runs	0.007	0.006	

Average of All 20 Runs

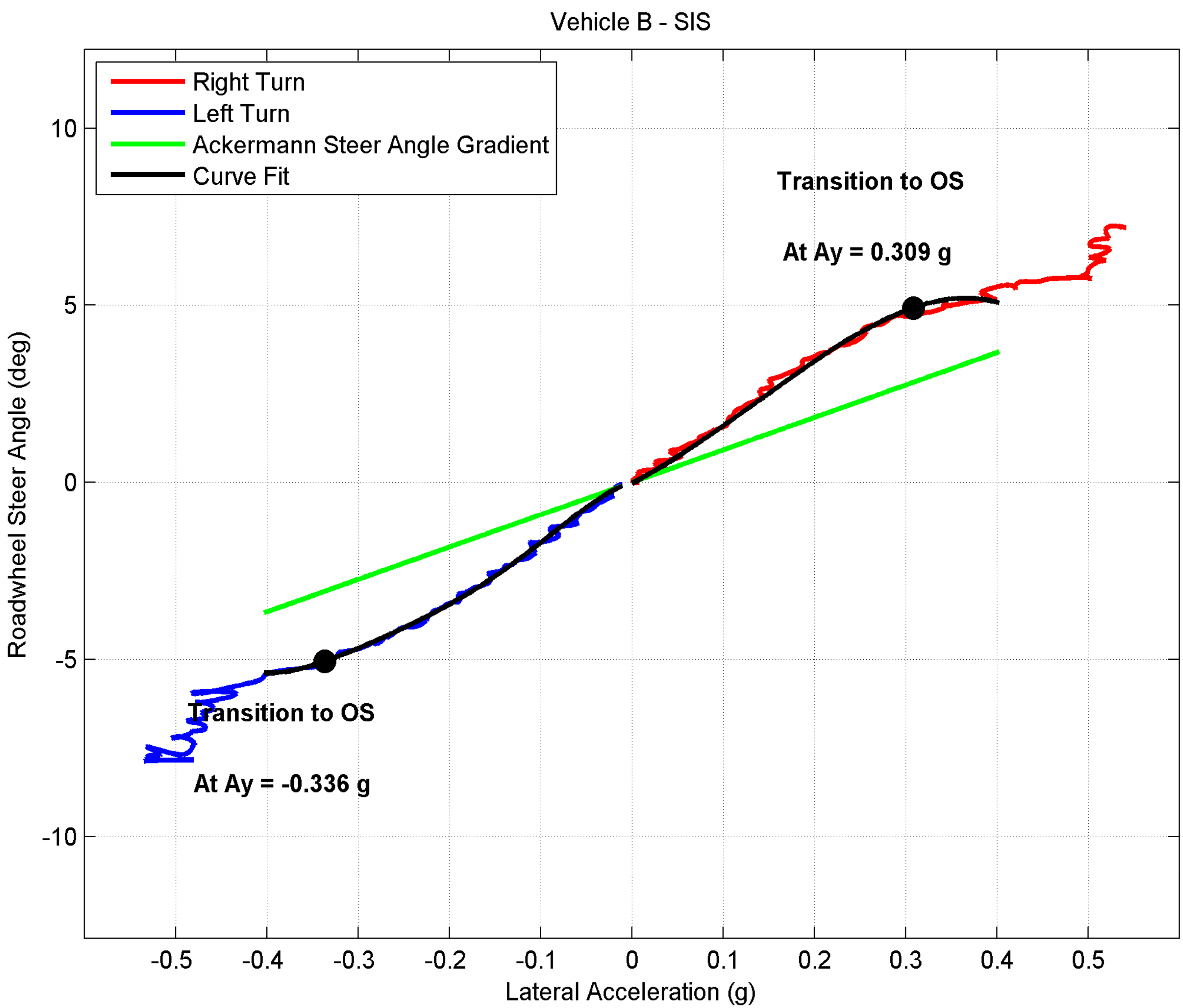
0.548

Threshold Ay

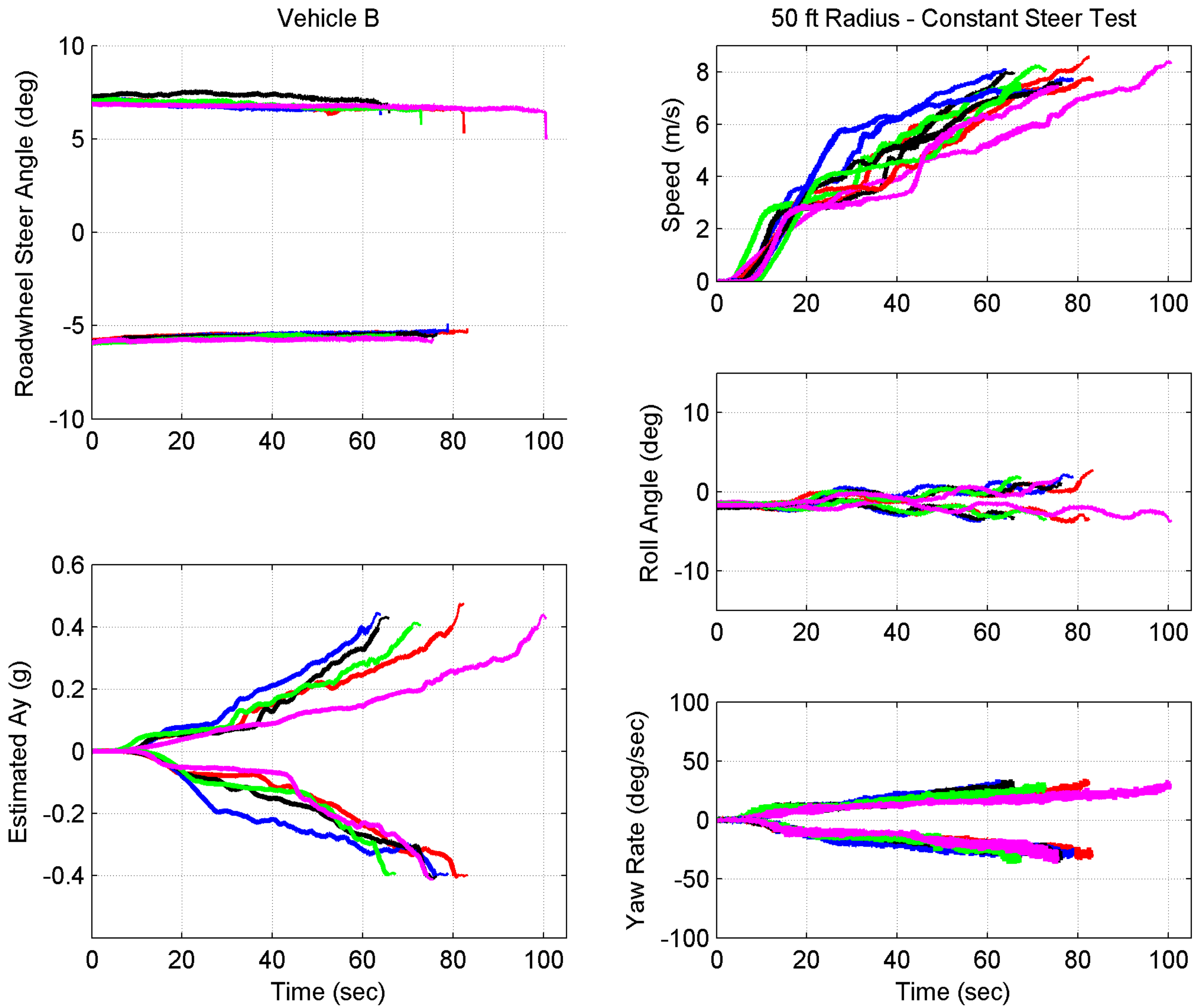
Run Number	Southbound Right Turns	Southbound Left Turns	Average of 10 Southbound Runs
1	0.5470	-0.5272	
2	0.5470	-0.5344	
3	0.5474	-0.5291	
4	0.5516	-0.5377	
5	0.5408	-0.5328	
Mean Value of 5 Runs	0.5468	-0.5322	**0.5395**
Standard Deviation of 5 Runs	0.004	0.004	



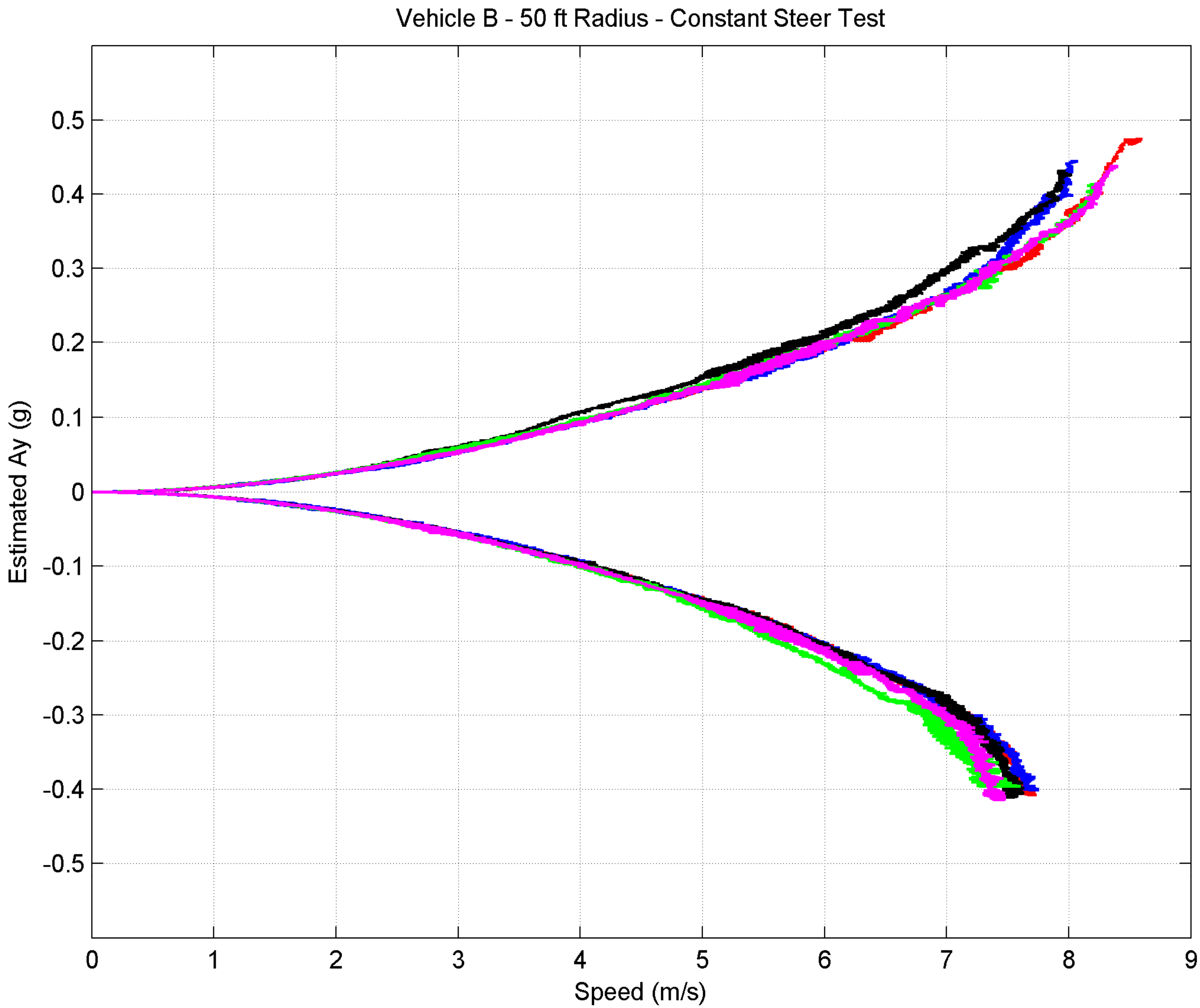
Vehicle B - SIS
Roadwheel Steer (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



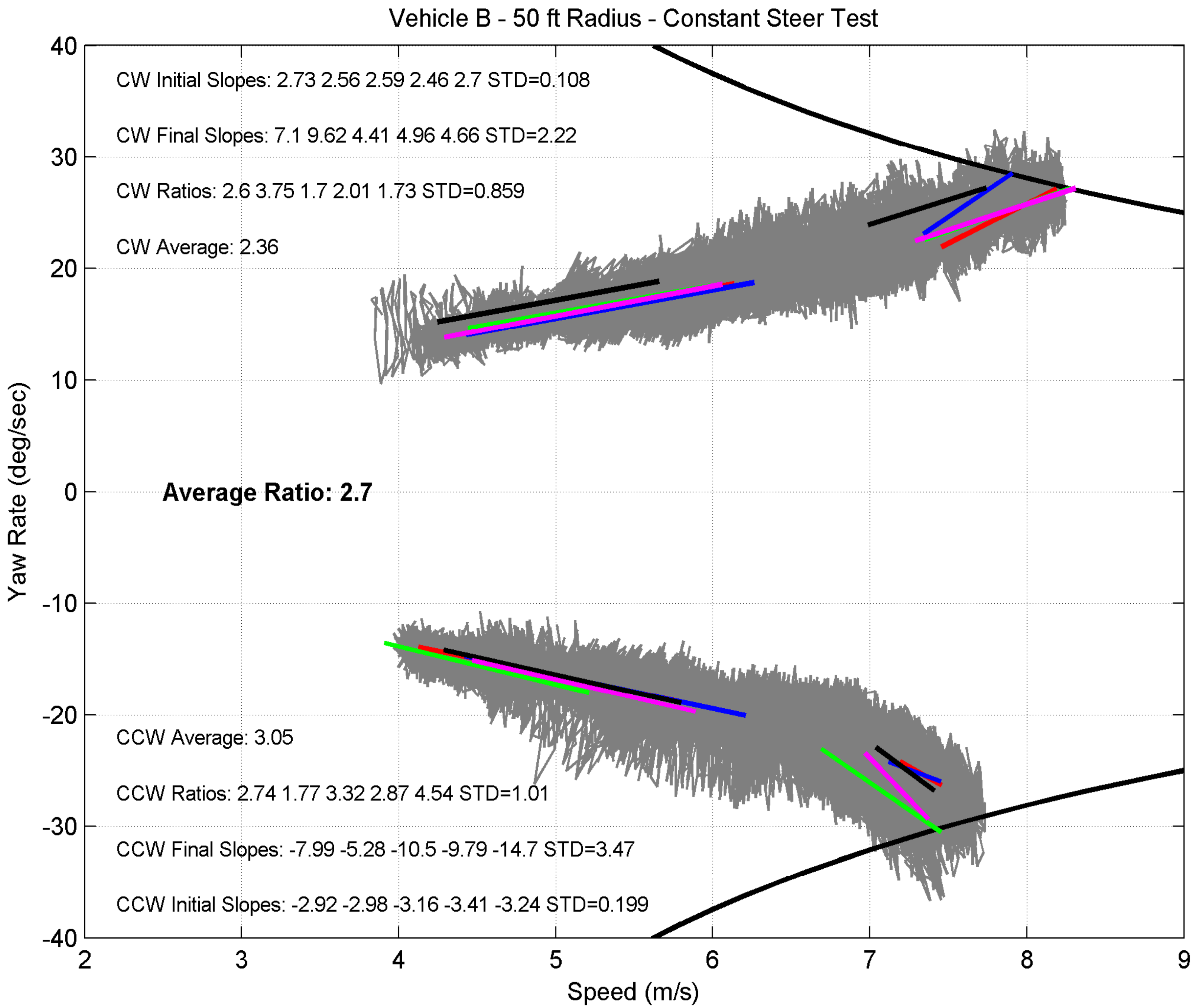
Vehicle B - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to OS
At Ay = 0.309 g
Transition to OS
At Ay = -0.336 g
Roadwheel Steer Angle (deg)
10
5
0
-5
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)



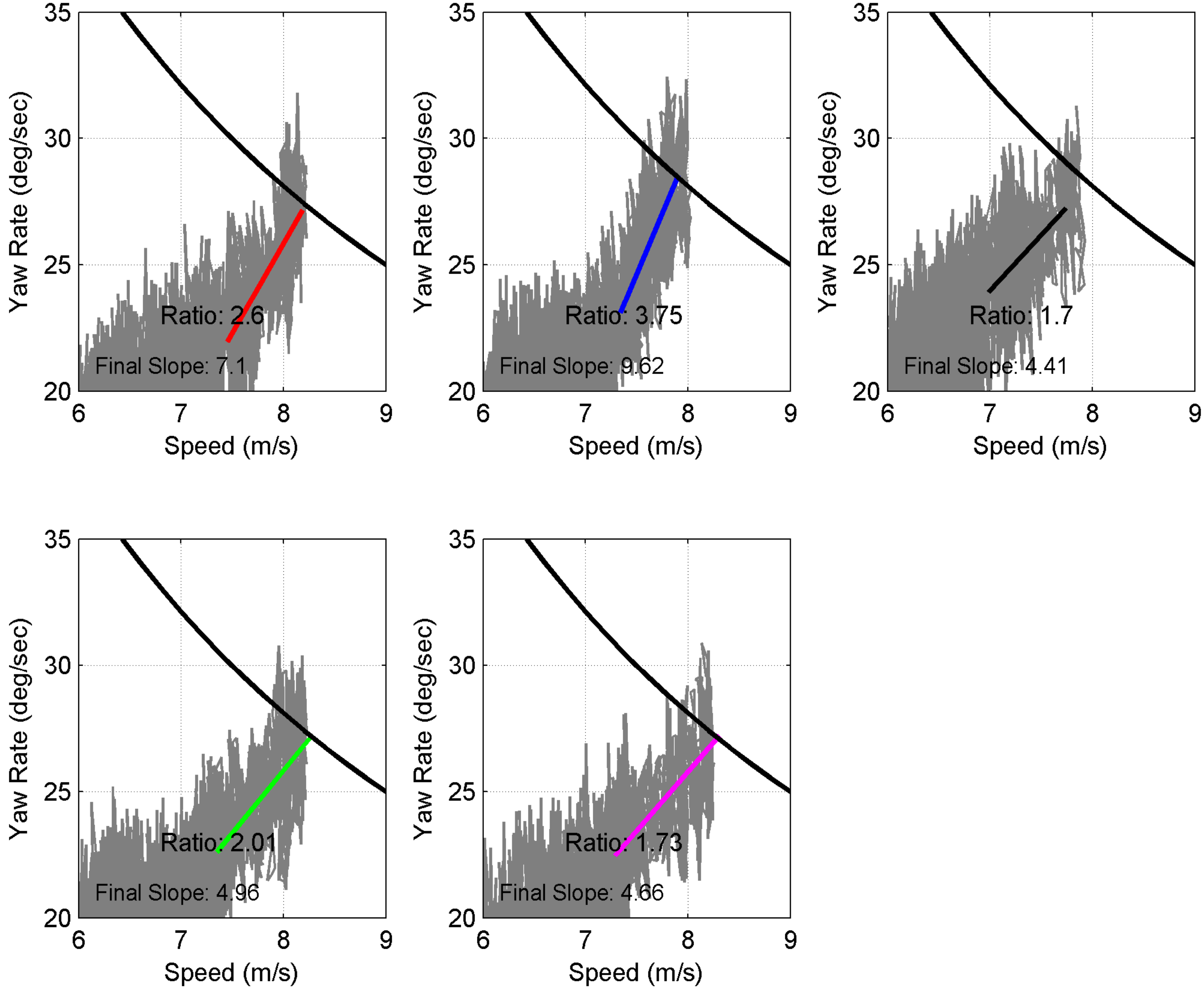
Vehicle B
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

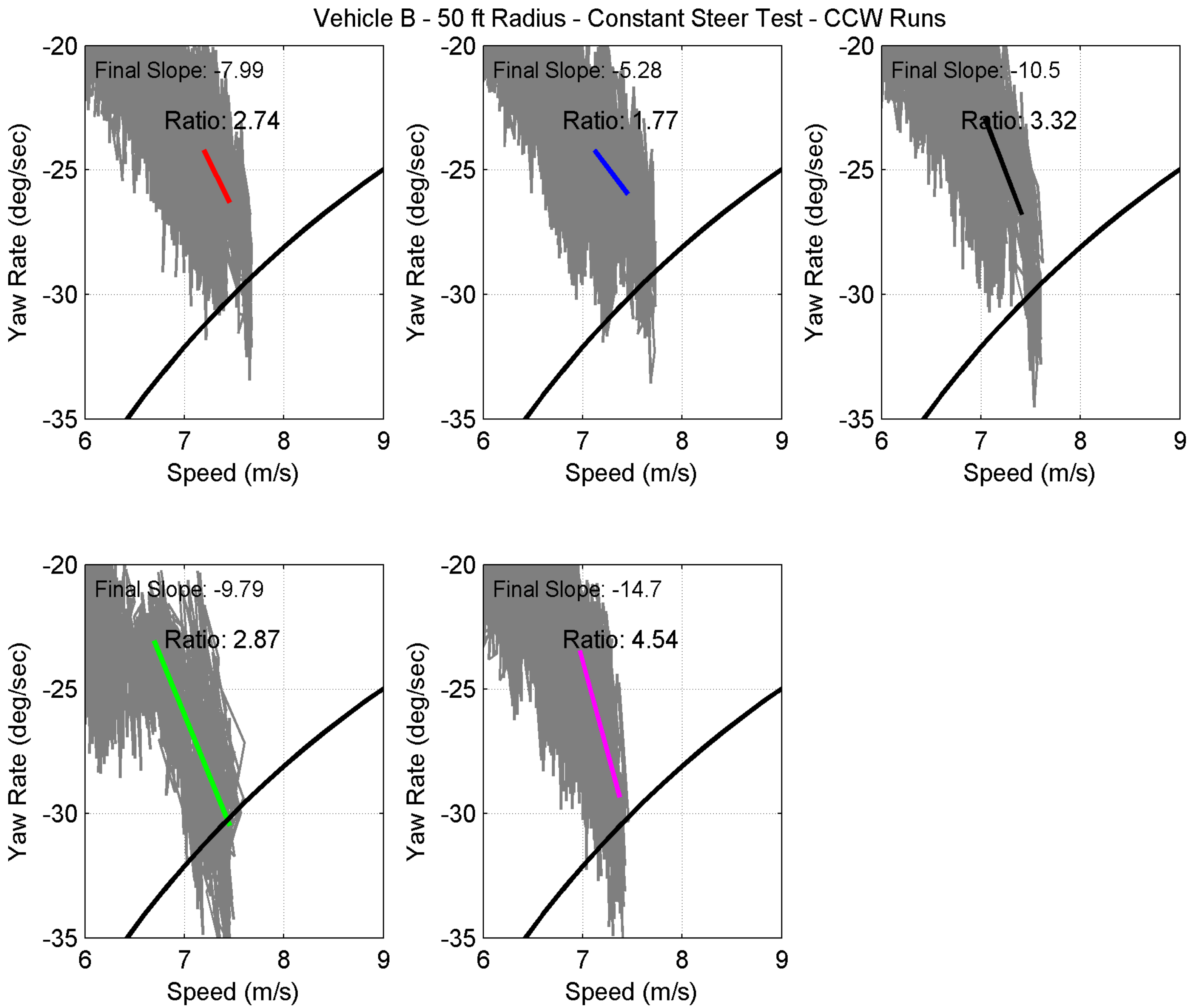


Vehicle B - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
Speed (m/s)

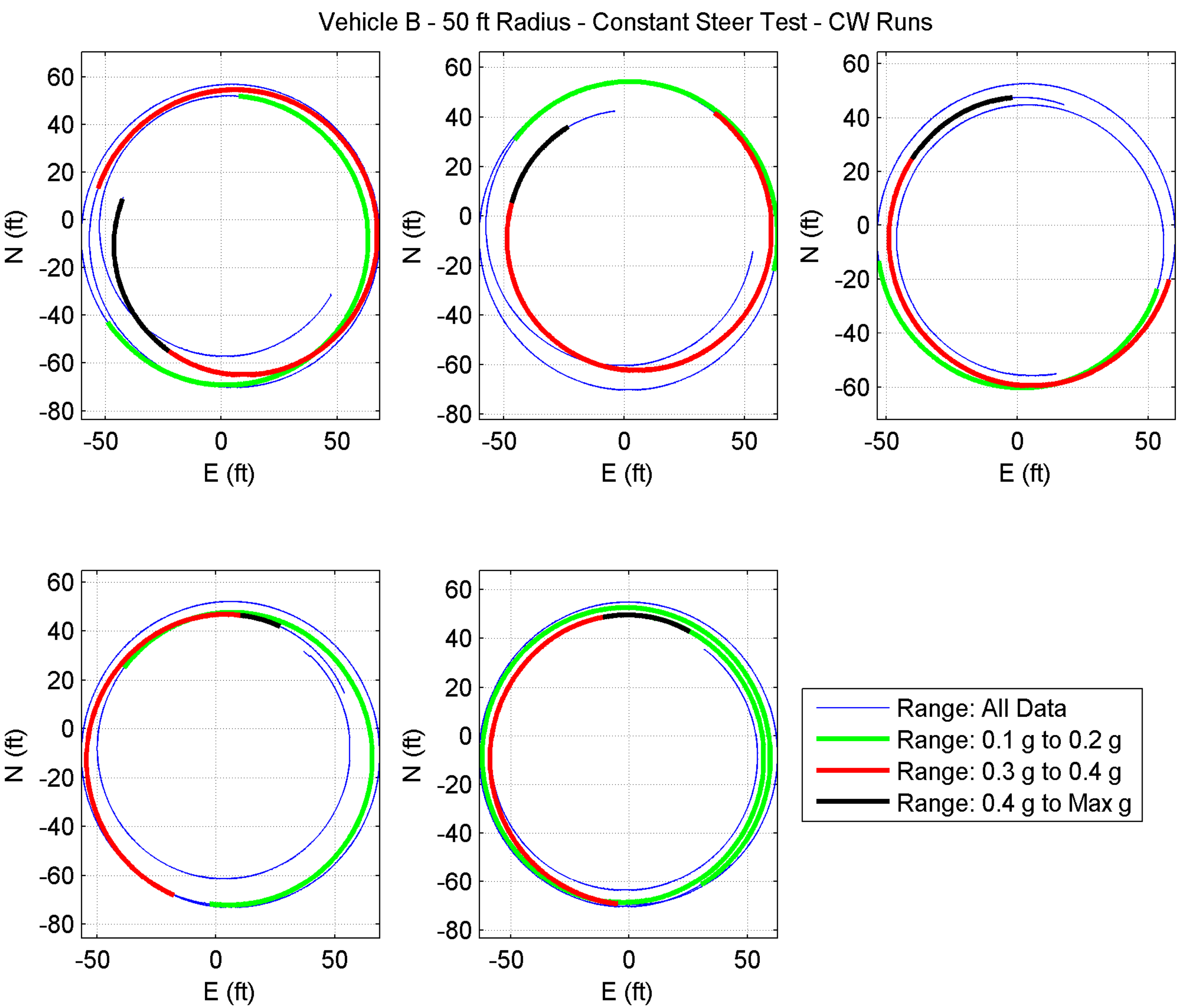

Vehicle B - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 2.73 2.56 2.59 2.46 2.7 STD=0.108
CW Final Slopes: 7.1 9.62 4.41 4.96 4.66 STD=2.22
CW Ratios: 2.6 3.75 1.7 2.01 1.73 STD=0.859
CW Average: 2.36
Average Ratio: 2.7
CCW Average: 3.05
CCW Ratios: 2.74 1.77 3.32 2.87 4.54 STD=1.01
CCW Final Slopes: -7.99 -5.28 -10.5 -9.79 -14.7 STD=3.47
CCW Initial Slopes: -2.92 -2.98 -3.16 -3.41 -3.24 STD=0.199
Yaw Rate (deg/sec)
Speed (m/s)
40
30
20
10
0
-10
-20
-30
-40
2
3
4
5
6
7
8
9

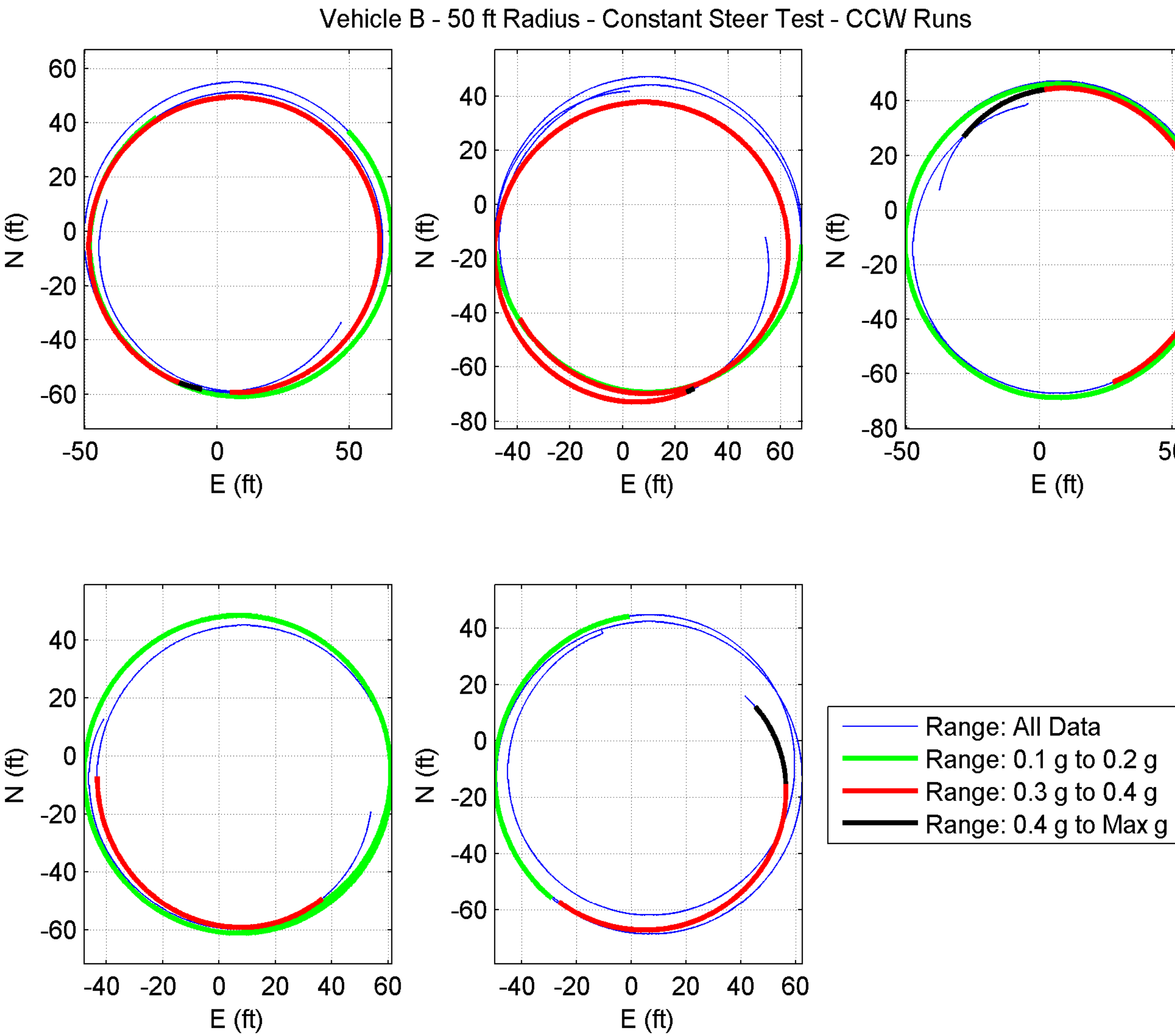
Vehicle B - 50 ft Radius - Constant Steer Test - CW Runs



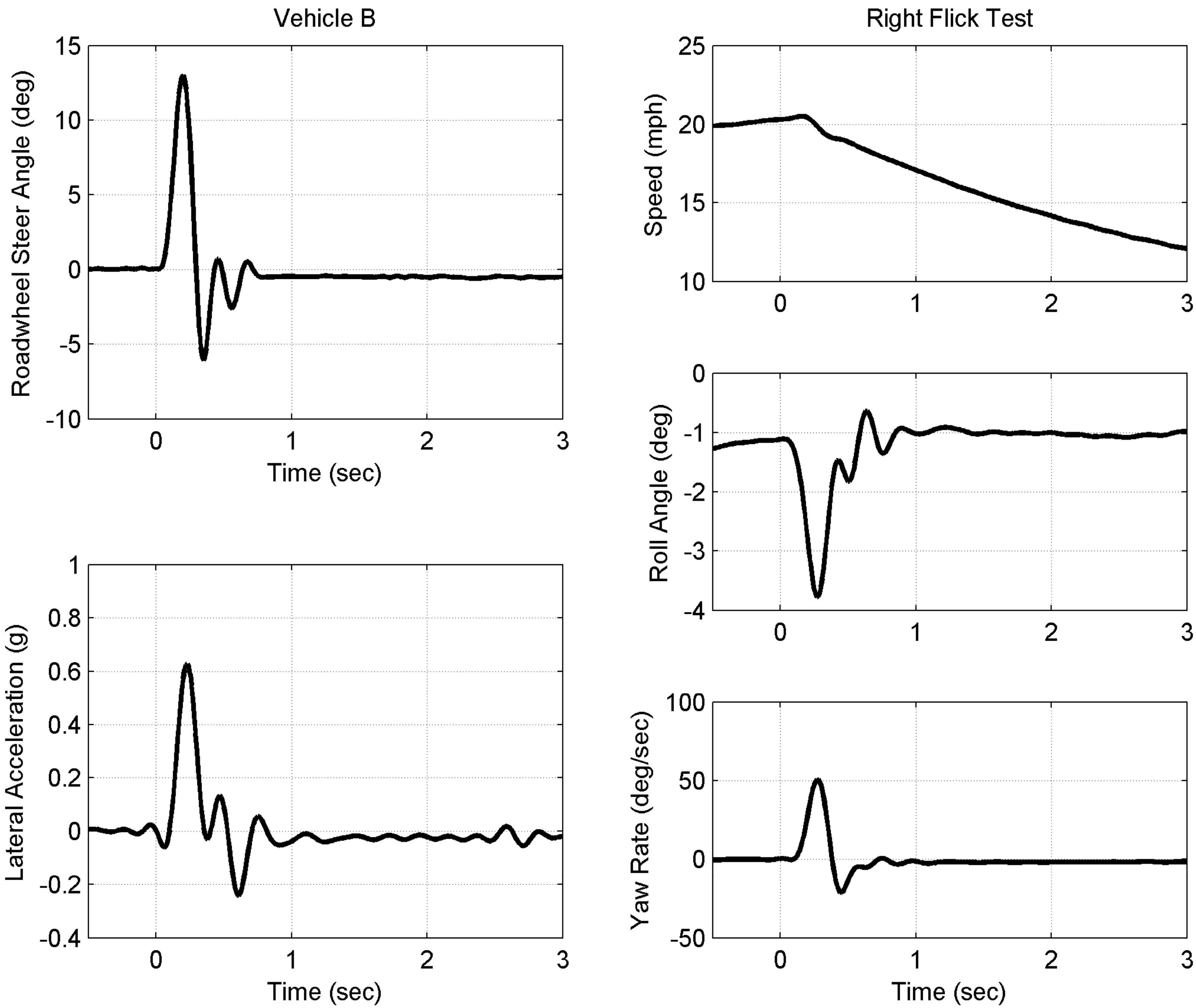


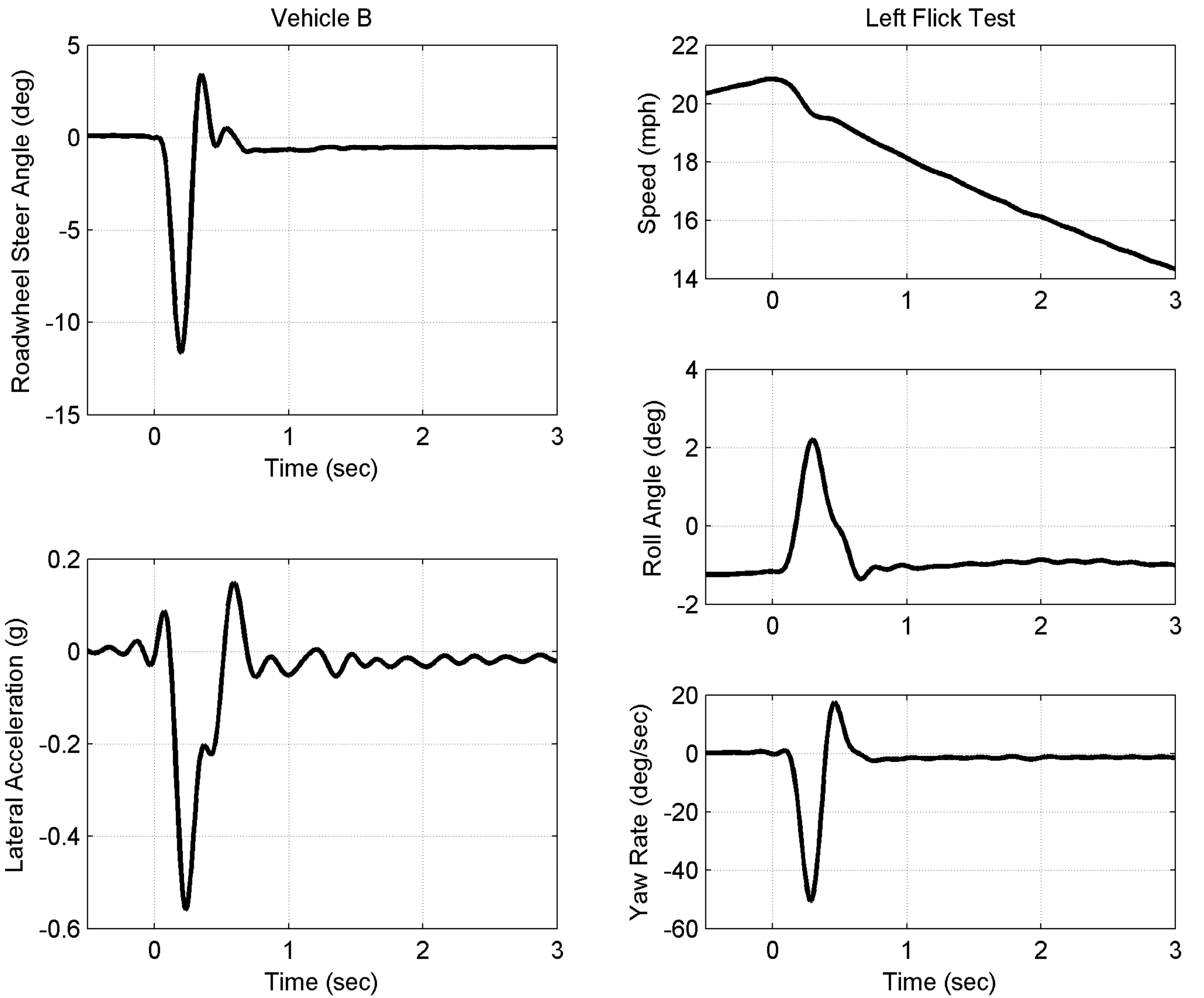
Vehicle B - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -7.99
Ratio: 2.74
Final Slope: -5.28
Ratio: 1.77
Final Slope: -10.5
Ratio: 3.32
Final Slope: -9.79
Ratio: 2.87
Final Slope: -14.7
Ratio: 4.54
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

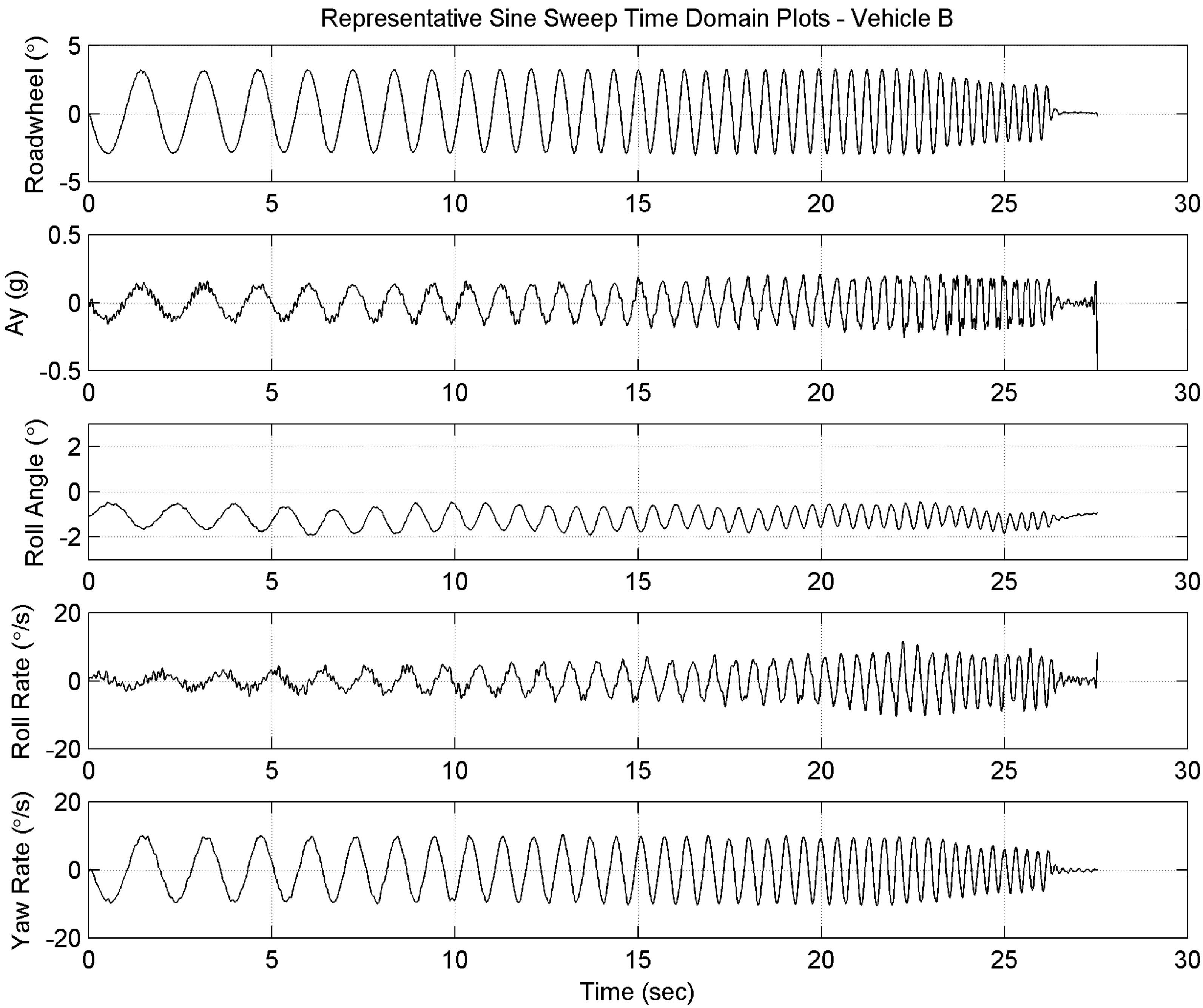

Vehicle B - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

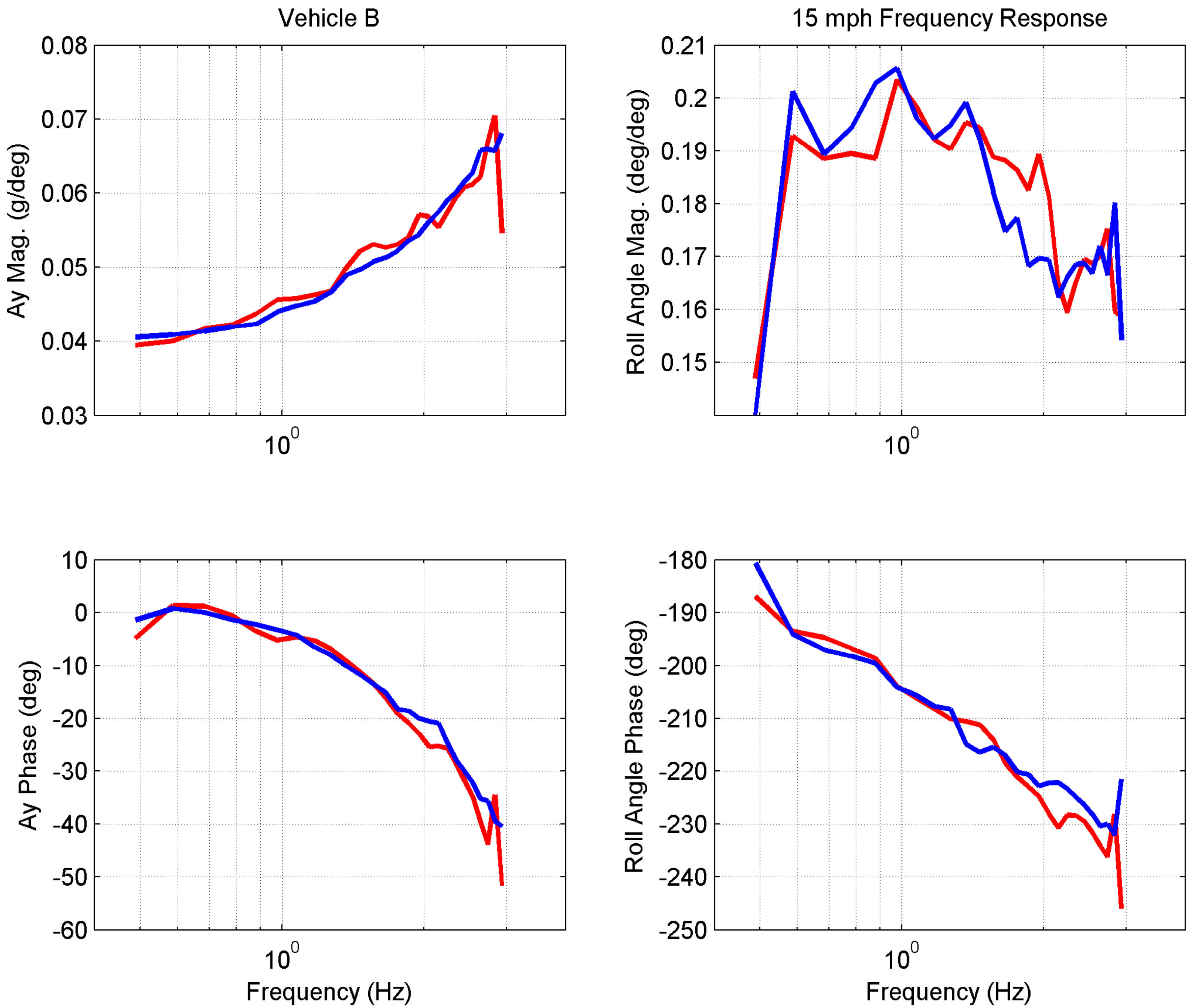


Vehicle B - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

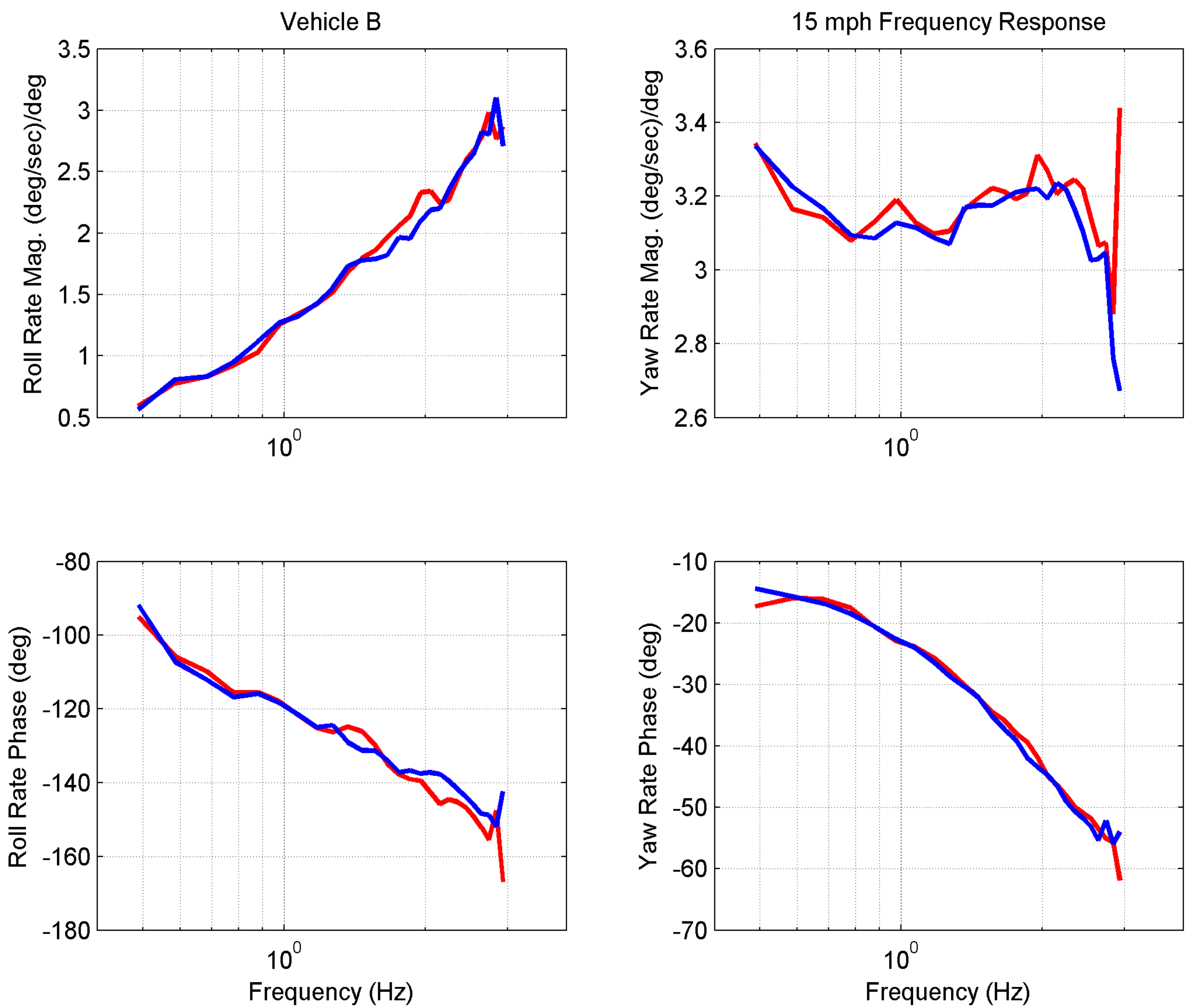

Vehicle B
Right Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle B
Left Flick Test
Roadwheel Steer Angle (deg)
5
0
-5
-10
-15
0
1
2
3
Time (sec)
Speed (mph)
22
20
18
16
14
Lateral Acceleration (g)
0.2
0
-0.2
-0.4
-0.6
Roll Angle (deg)
4
2
0
-2
Yaw Rate (deg/sec)
20
0
-20
-40
-60

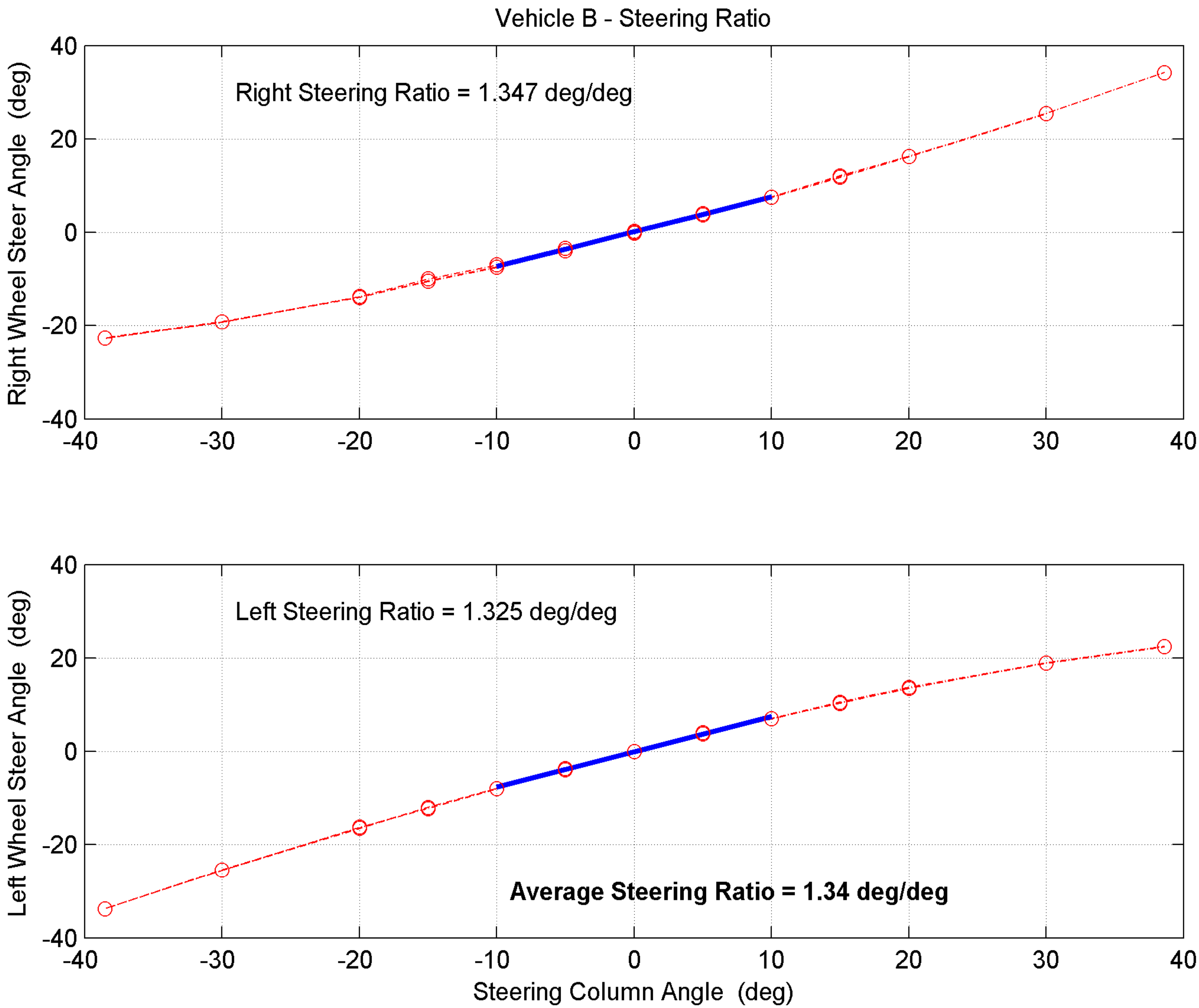

Representative Sine Sweep Time Domain Plots - Vehicle B
Roadwheel (°)
5
0
-5
Ay (g)
0.5
0
-0.5
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
20
0
-20
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)

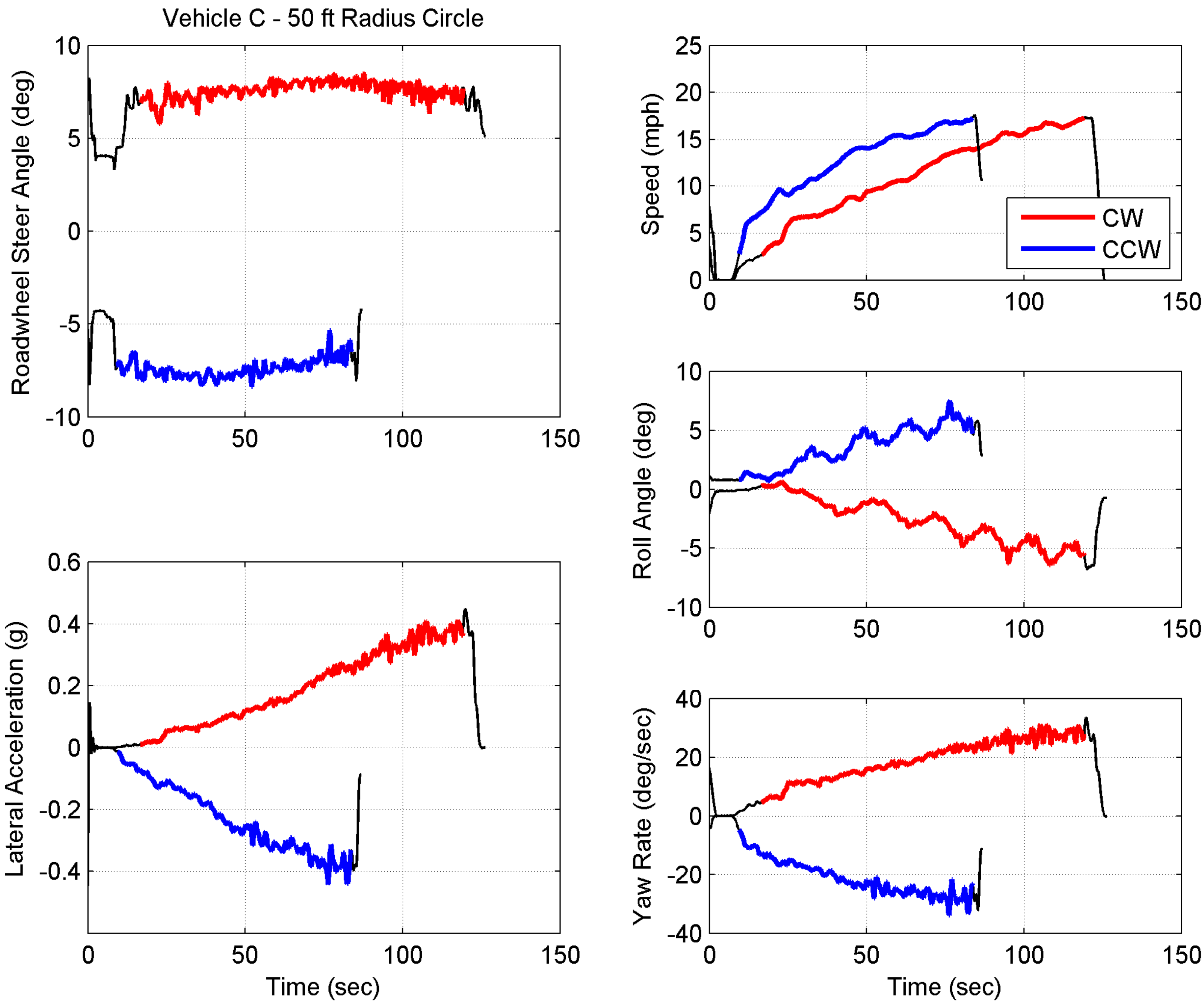


Vehicle B
15 mph Frequency Response
Ay Mag. (g/deg)
0.08
0.07
0.06
0.05
0.04
0.03
10^0
Roll Angle Mag. (deg/deg)
0.21
0.2
0.19
0.18
0.17
0.16
0.15
Ay Phase (deg)
10
0
-10
-20
-30
-40
-50
-60
Frequency (Hz)
Roll Angle Phase (deg)
-180
-190
-200
-210
-220
-230
-240
-250

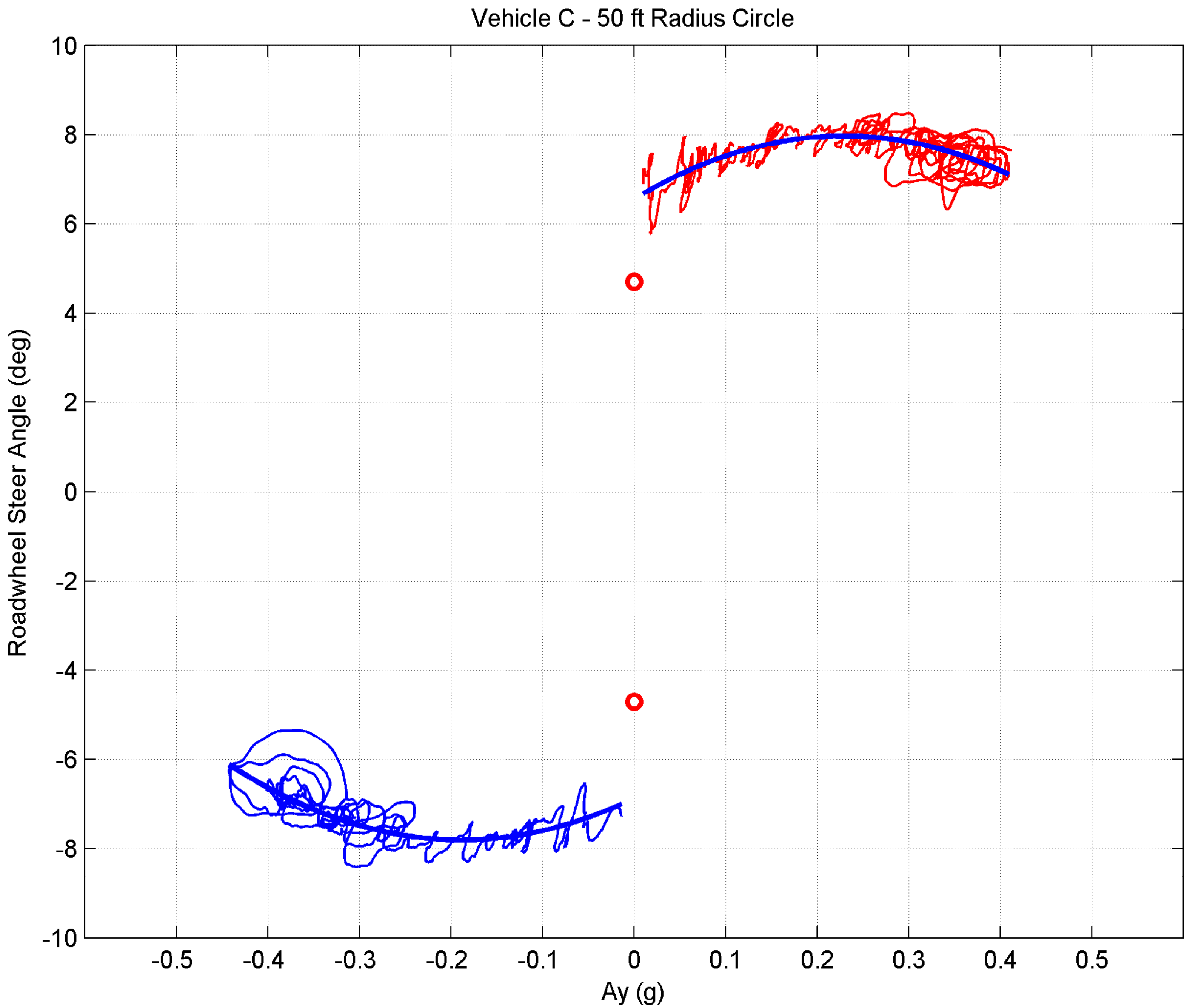


Vehicle B
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
3.5
3
2.5
2
1.5
1
0.5
10^0
Yaw Rate Mag. (deg/sec)/deg
3.6
3.4
3.2
3
2.8
2.6
10^0
Roll Rate Phase (deg)
-80
-100
-120
-140
-160
-180
10^0
Frequency (Hz)
Yaw Rate Phase (deg)
-10
-20
-30
-40
-50
-60
-70
10^0
Frequency (Hz)

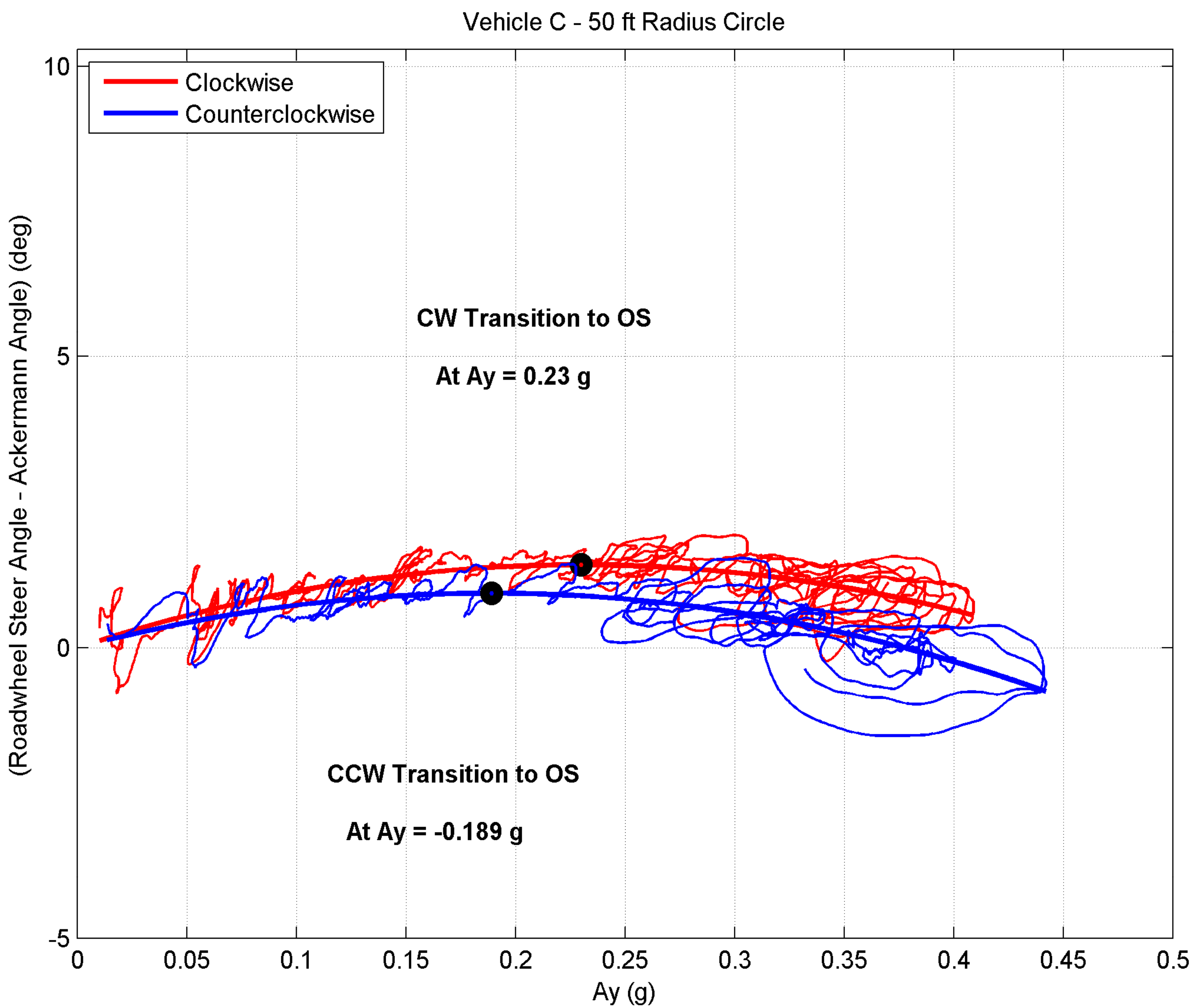

Vehicle B - Steering Ratio
Right Steering Ratio = 1.347 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-40
-30
-20
-10
0
10
20
30
40
Left Steering Ratio = 1.325 deg/deg
Average Steering Ratio = 1.34 deg/deg
Left Wheel Steer Angle (deg)
Steering Column Angle (deg)

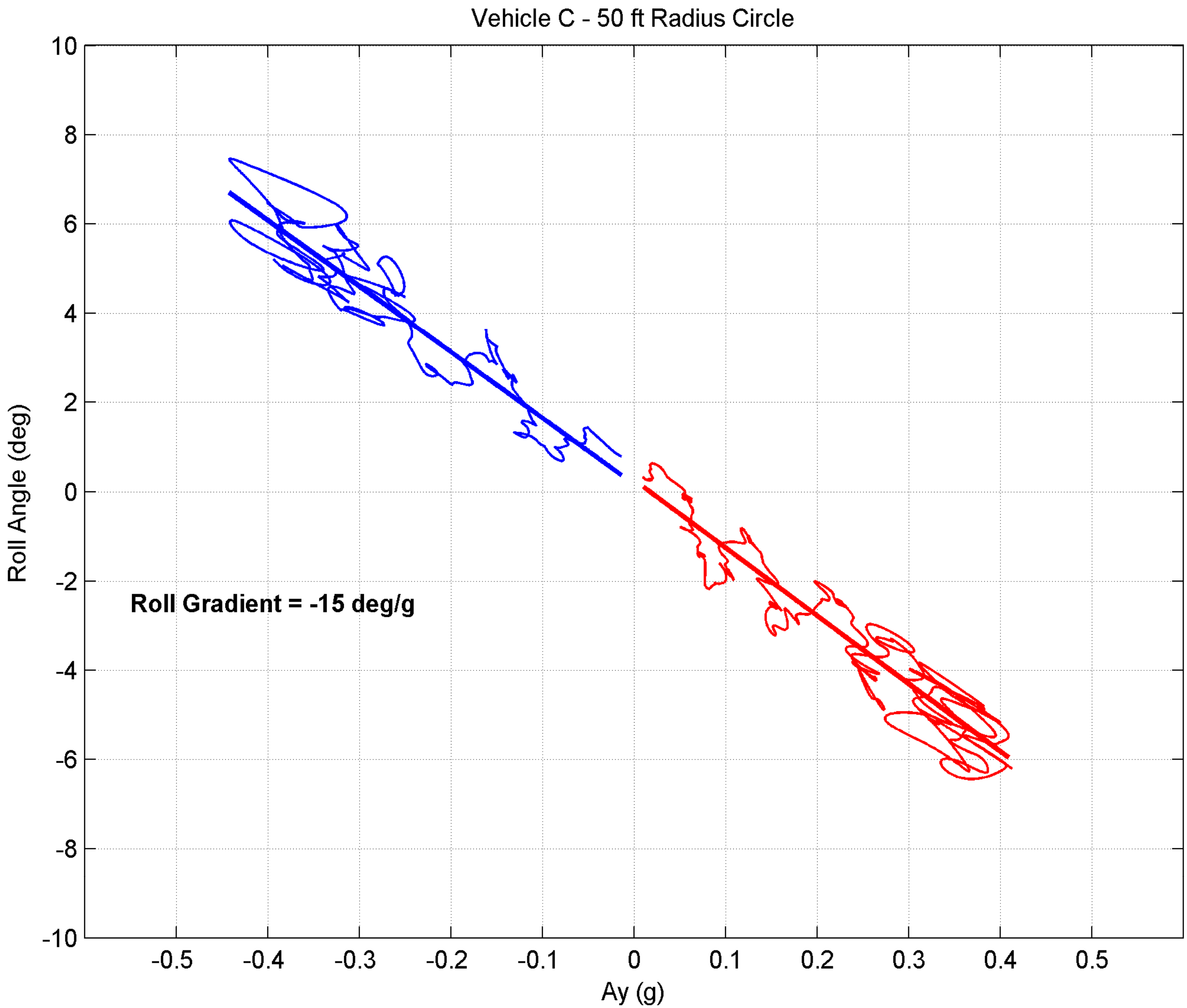


Vehicle C - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
CW
CCW
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

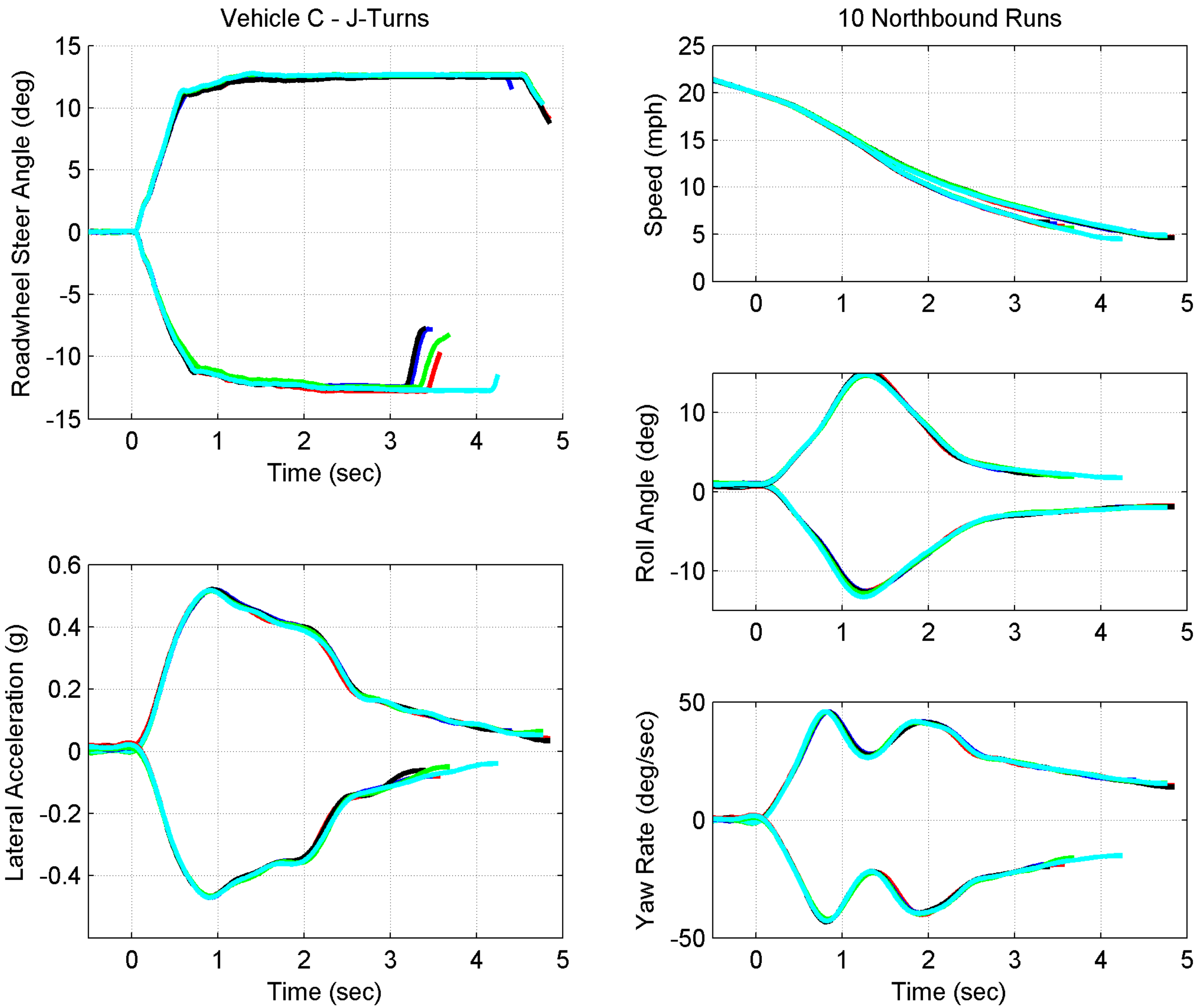


Vehicle C - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5


Vehicle C - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.23 g
CCW Transition to OS
At Ay = -0.189 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

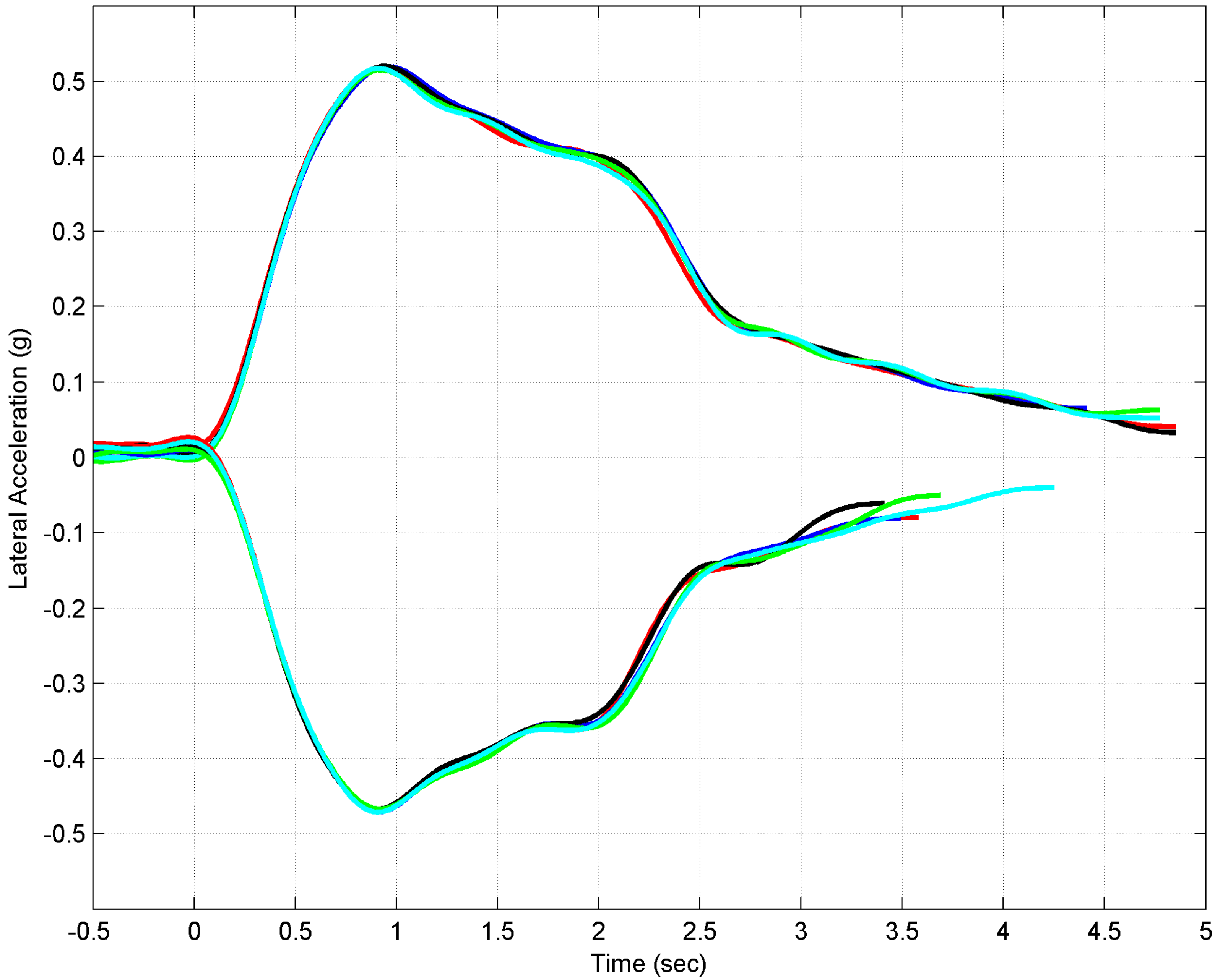


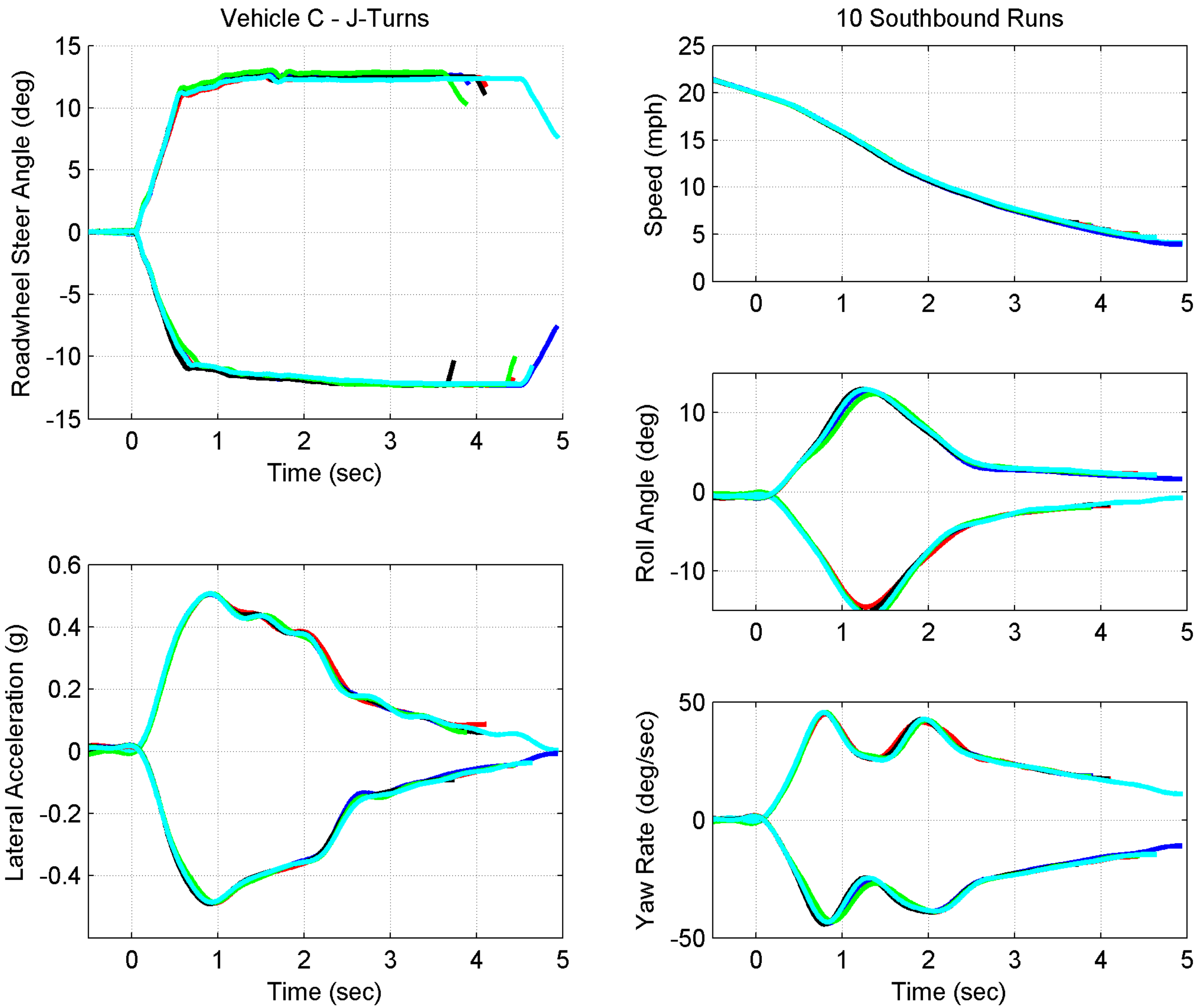
Vehicle C - 50 ft Radius Circle
10
8
6
4
2
0
-2
-4
-6
-8
-10
Roll Angle (deg)
Roll Gradient = -15 deg/g
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)



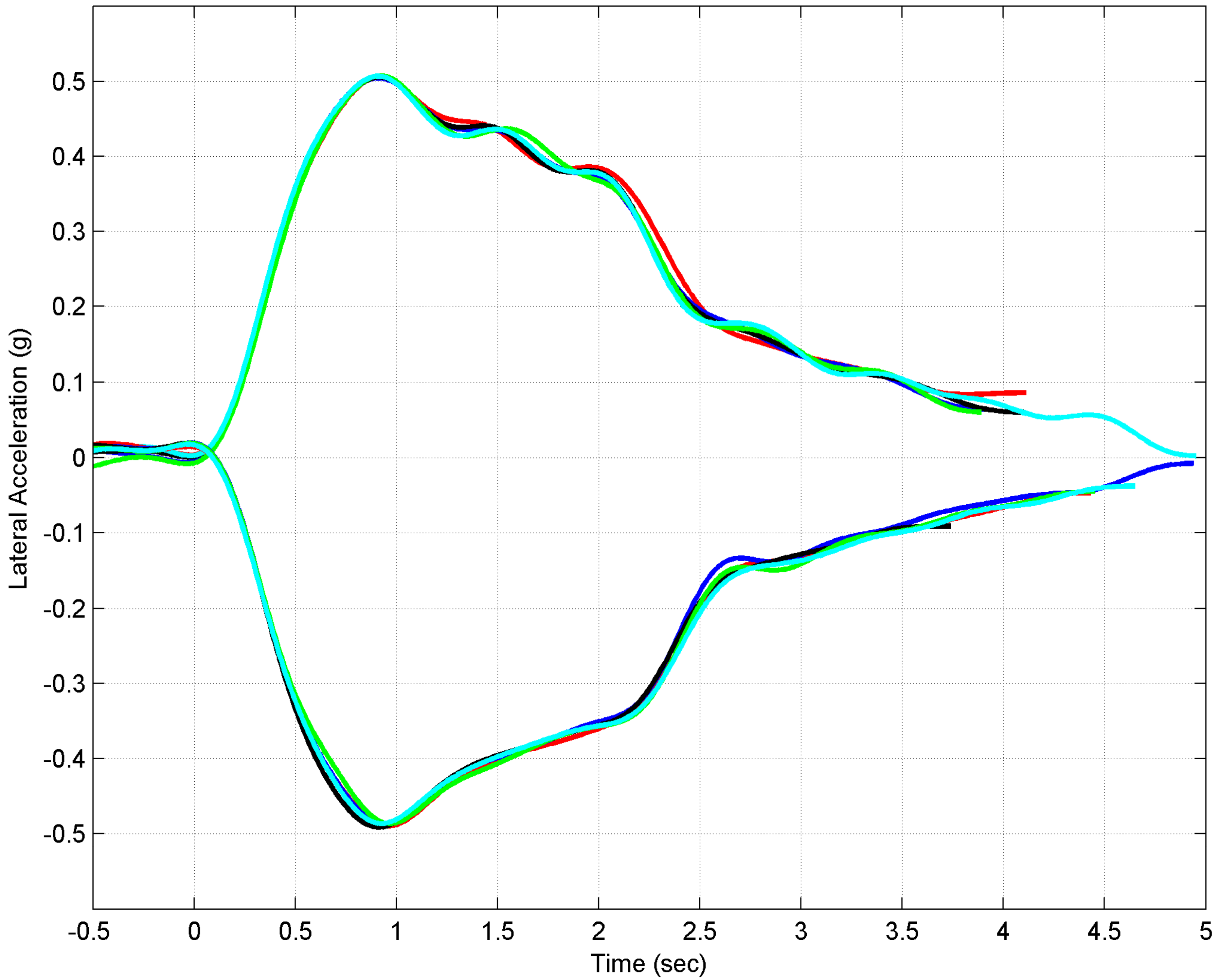
Vehicle C - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

Vehicle C - J-Turns - 10 Northbound Runs




Vehicle C - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

Vehicle C - J-Turns - 10 Southbound Runs



Vehicle C

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

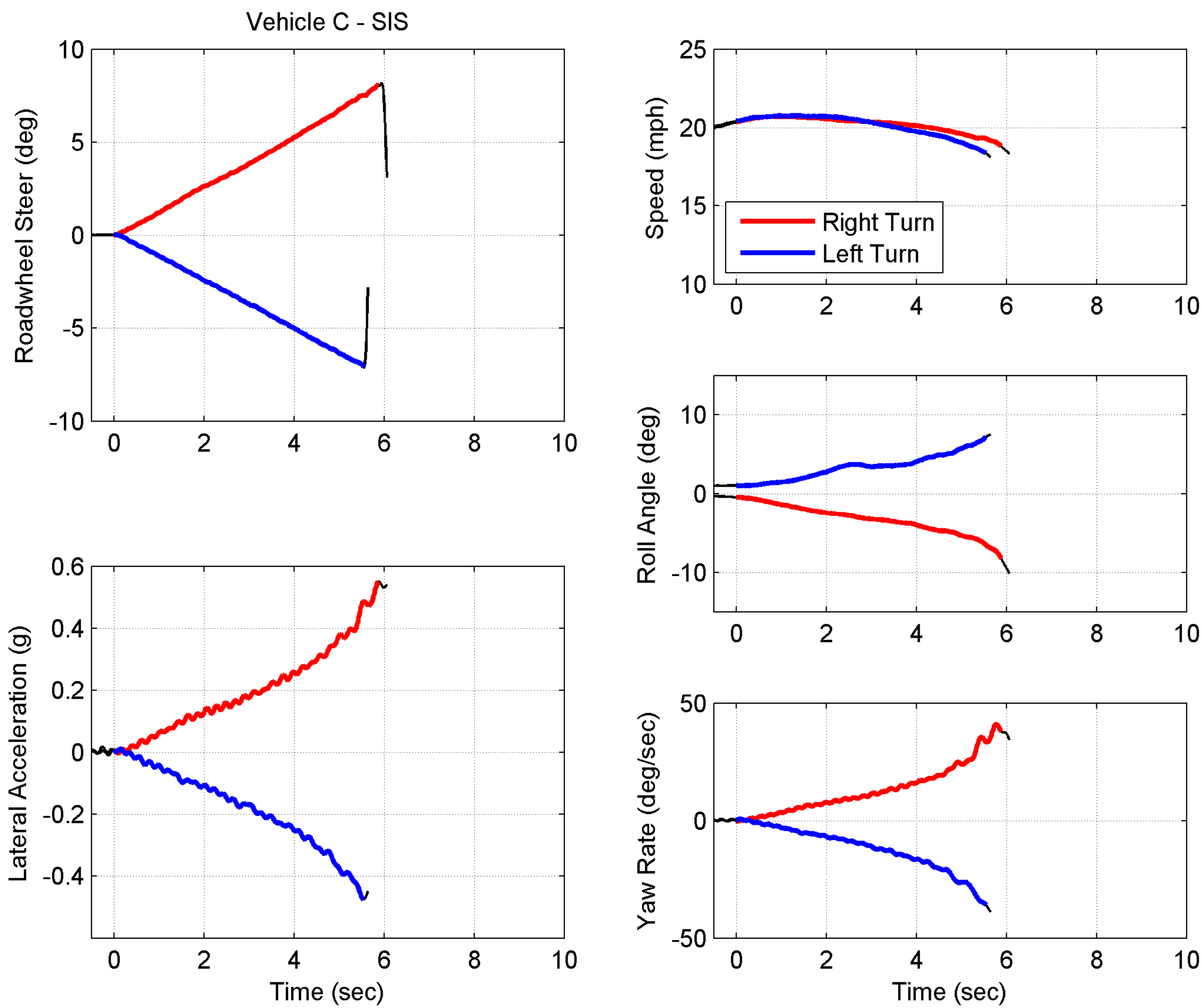
Run Number	Northbound Right Turns	Northbound Left Turns	
1	0.5170	-0.4676	
2	0.5198	-0.4710	
3	0.5201	-0.4670	
4	0.5153	-0.4669	
5	0.5173	-0.4713	**Average of 10 Northbound Runs**
Mean Value of 5 Runs	0.5179	-0.4687	**0.4933**
Standard Deviation of 5 Runs	0.002	0.002	

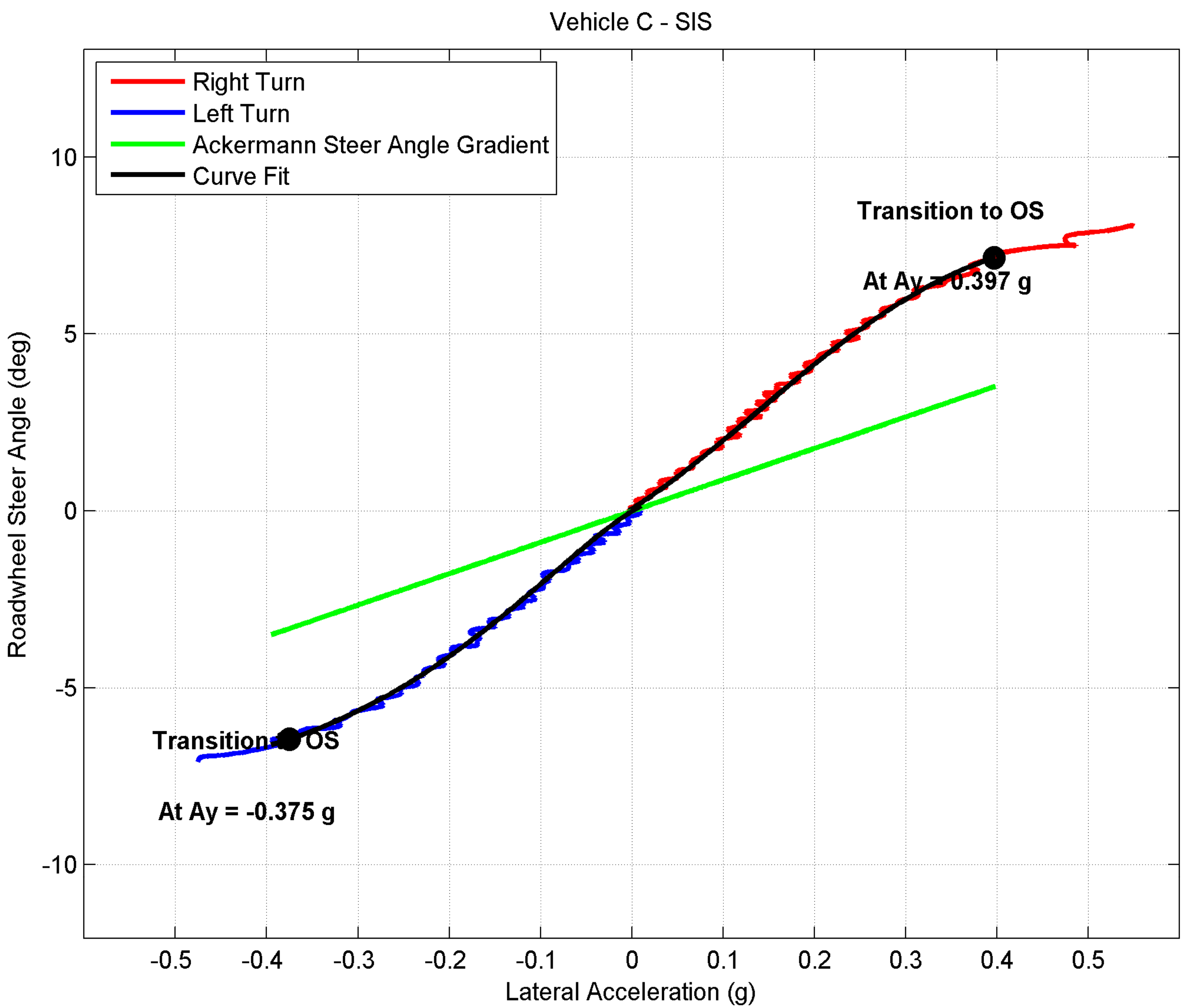
Run Number	Southbound Right Turns	Southbound Left Turns	
1	0.5058	-0.4896	
2	0.5045	-0.4878	
3	0.5056	-0.4912	
4	0.5075	-0.4864	
5	0.5069	-0.4864	**Average of 10 Southbound Runs**
Mean Value of 5 Runs	0.5060	-0.4883	**0.4972**
Standard Deviation of 5 Runs	0.001	0.002	

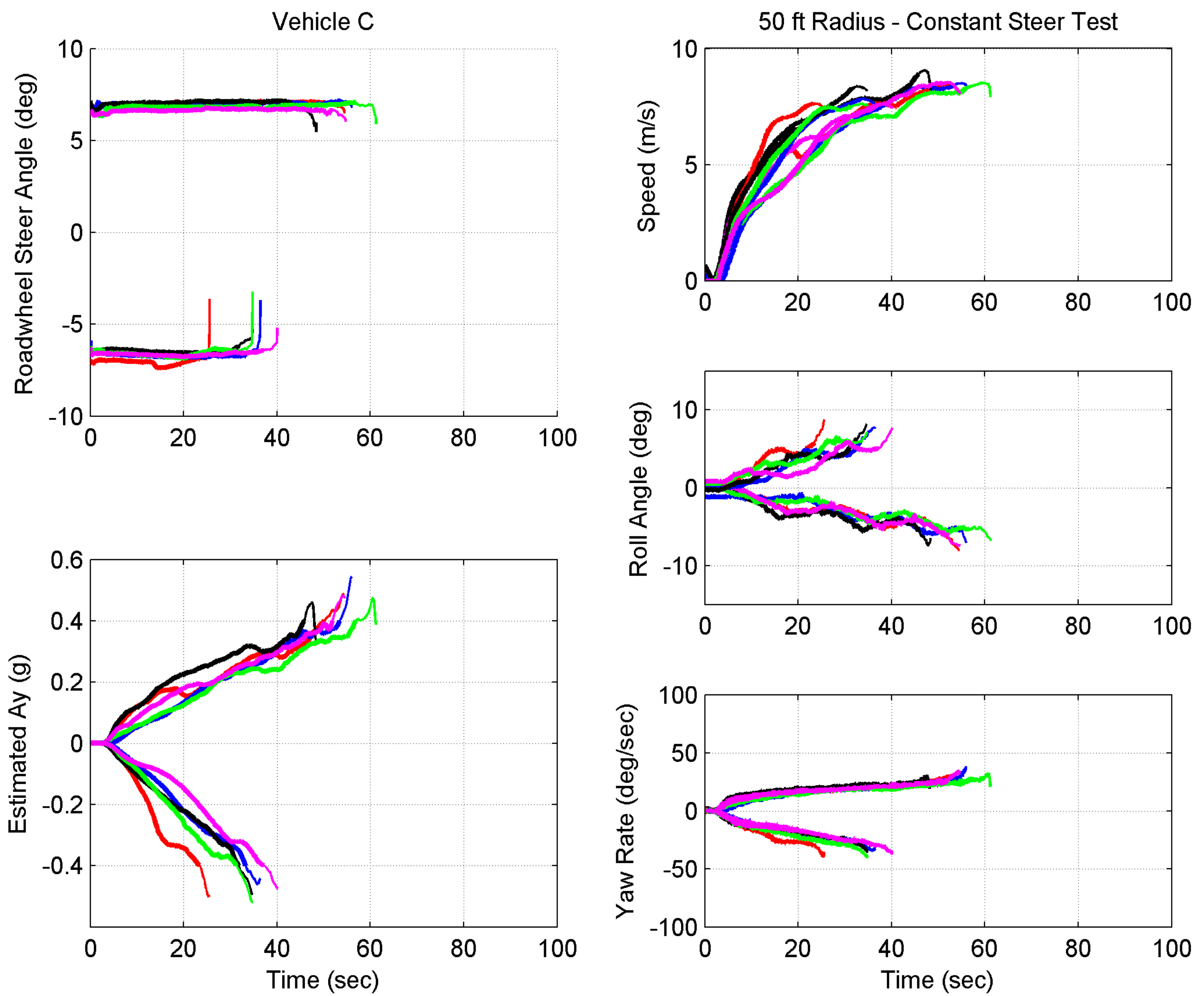
Average of All 20 Runs

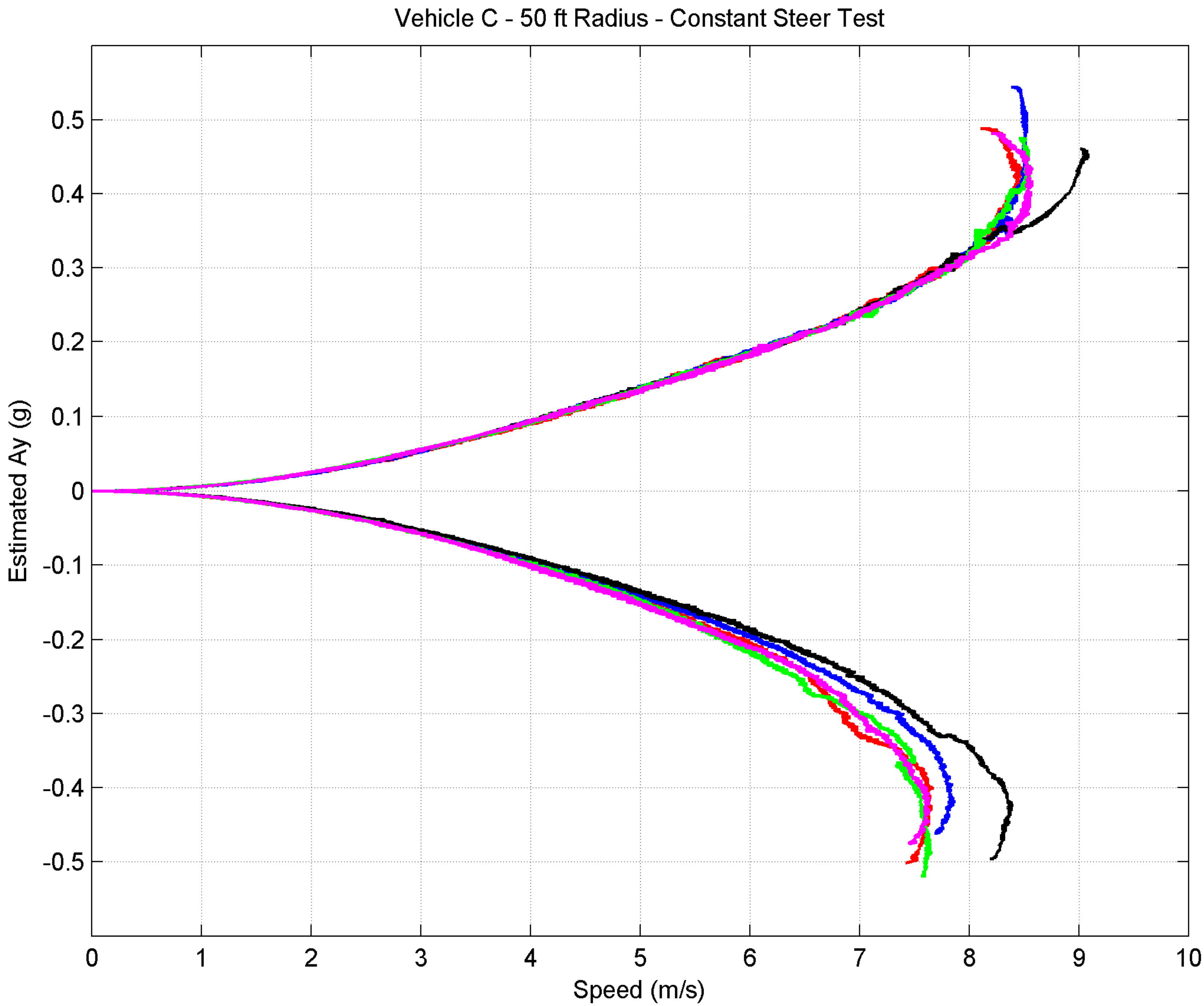
0.495

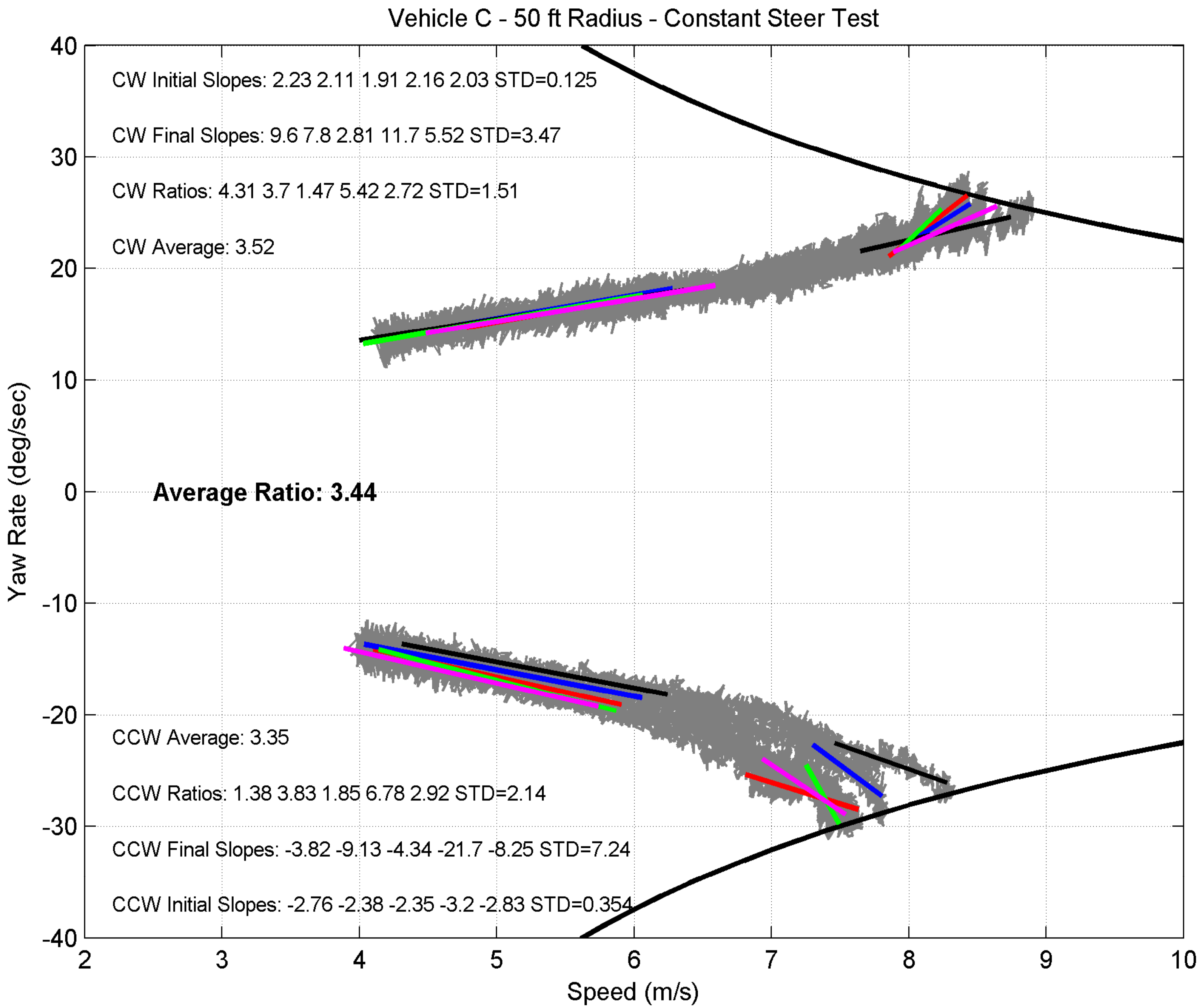
Threshold Ay

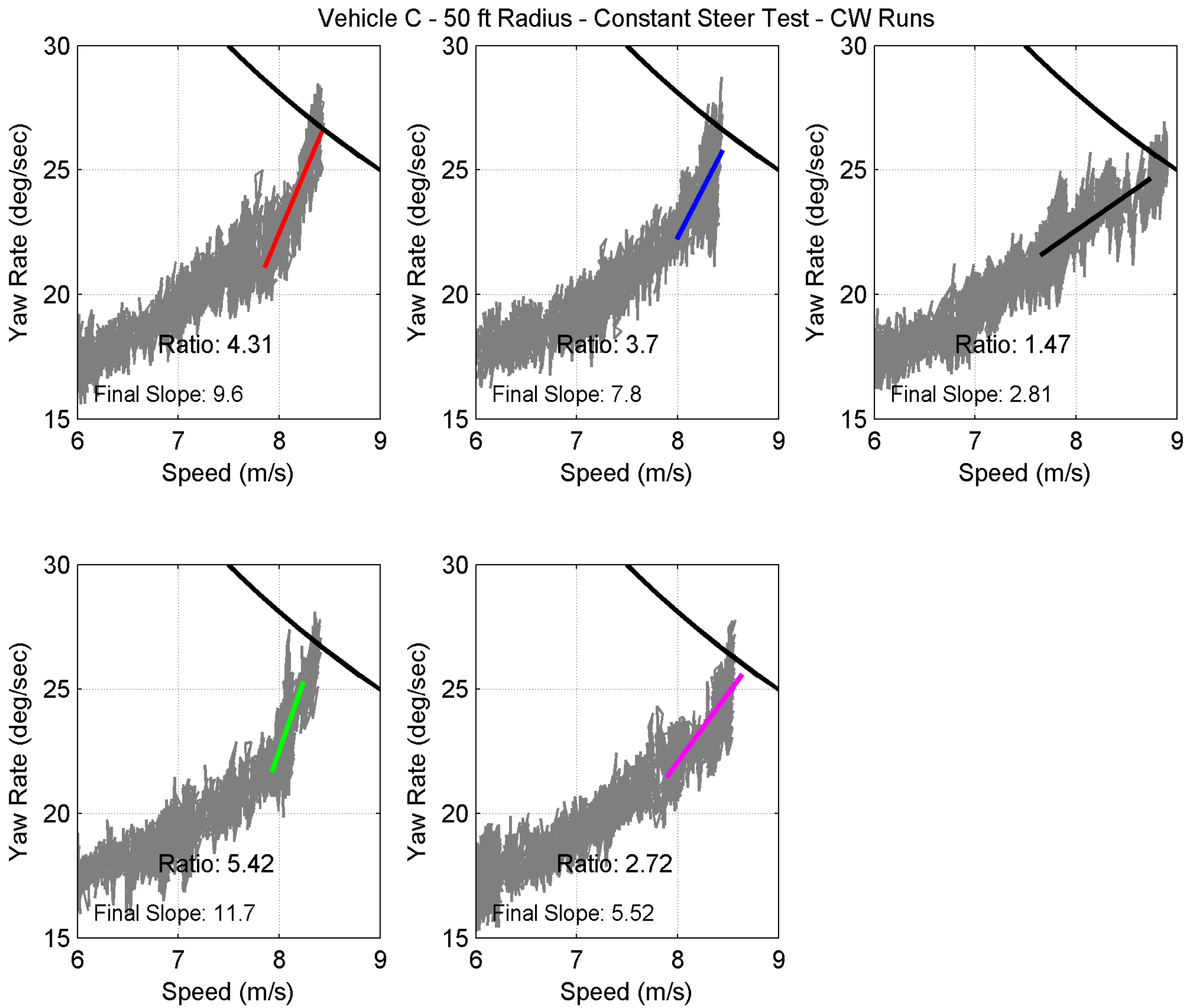

Vehicle C - SIS
Roadwheel Steer (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

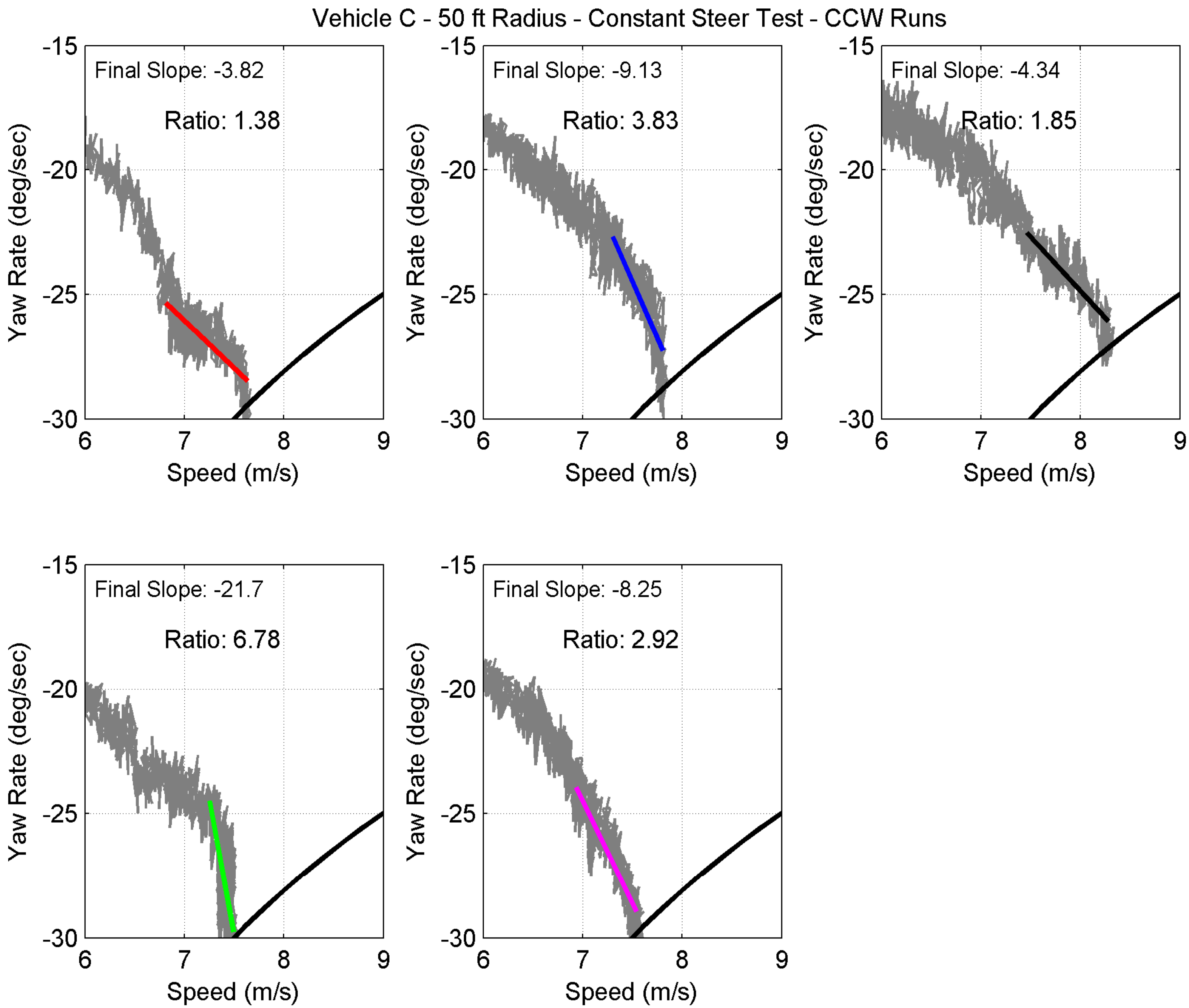

Vehicle C - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to OS
At Ay = 0.397 g
Transition to OS
At Ay = -0.375 g
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
10
5
0
-5
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5


Vehicle C
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
10
5
0
-5
-10
0
20
40
60
80
100
0.6
0.4
0.2
-0.2
-0.4
-100
-50
50

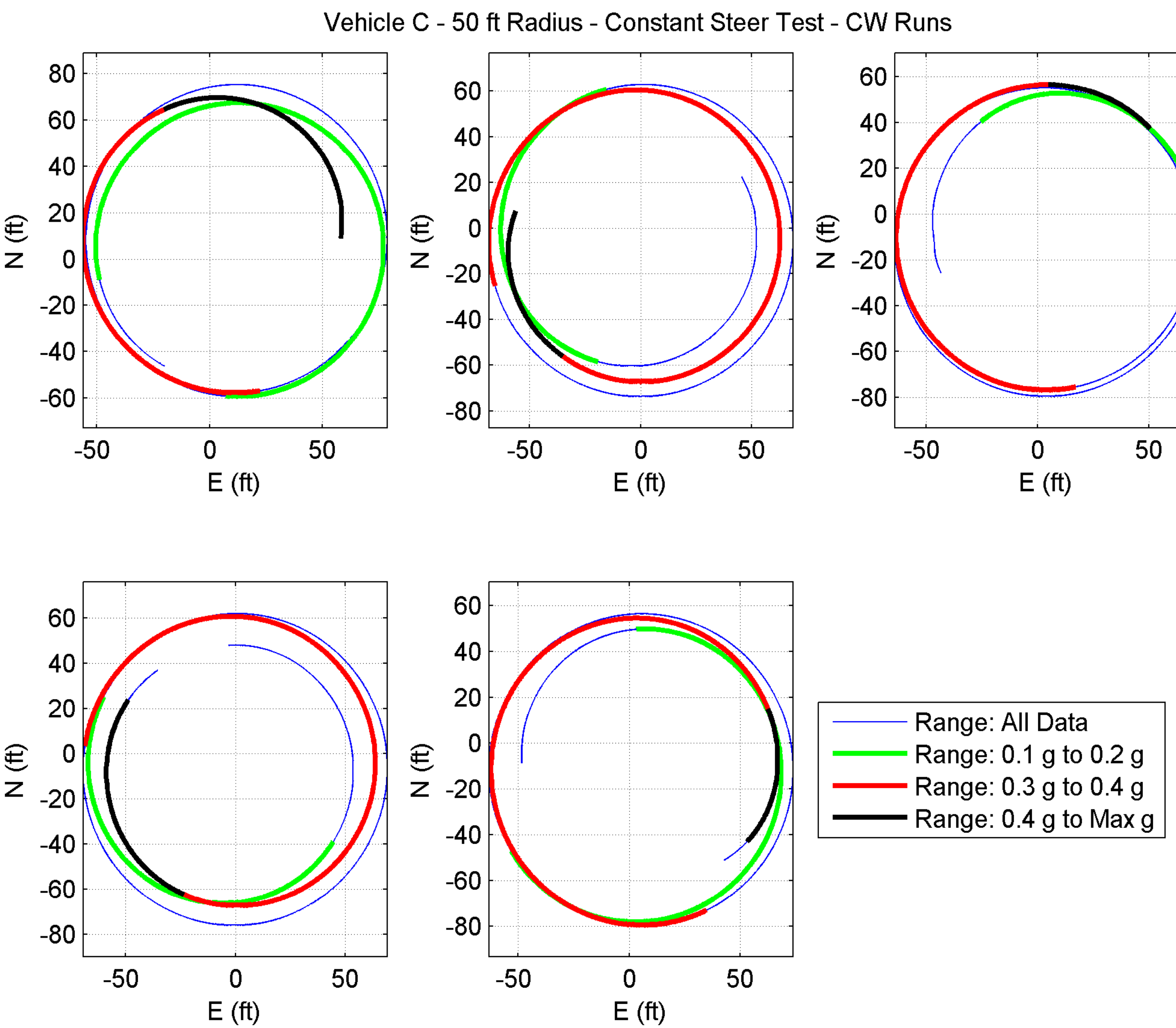

Vehicle C - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10
Speed (m/s)


Vehicle C - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 2.23 2.11 1.91 2.16 2.03 STD=0.125
CW Final Slopes: 9.6 7.8 2.81 11.7 5.52 STD=3.47
CW Ratios: 4.31 3.7 1.47 5.42 2.72 STD=1.51
CW Average: 3.52
Average Ratio: 3.44
CCW Average: 3.35
CCW Ratios: 1.38 3.83 1.85 6.78 2.92 STD=2.14
CCW Final Slopes: -3.82 -9.13 -4.34 -21.7 -8.25 STD=7.24
CCW Initial Slopes: -2.76 -2.38 -2.35 -3.2 -2.83 STD=0.354
Yaw Rate (deg/sec)
Speed (m/s)
40
30
20
10
0
-10
-20
-30
-40
2
3
4
5
6
7
8
9
10

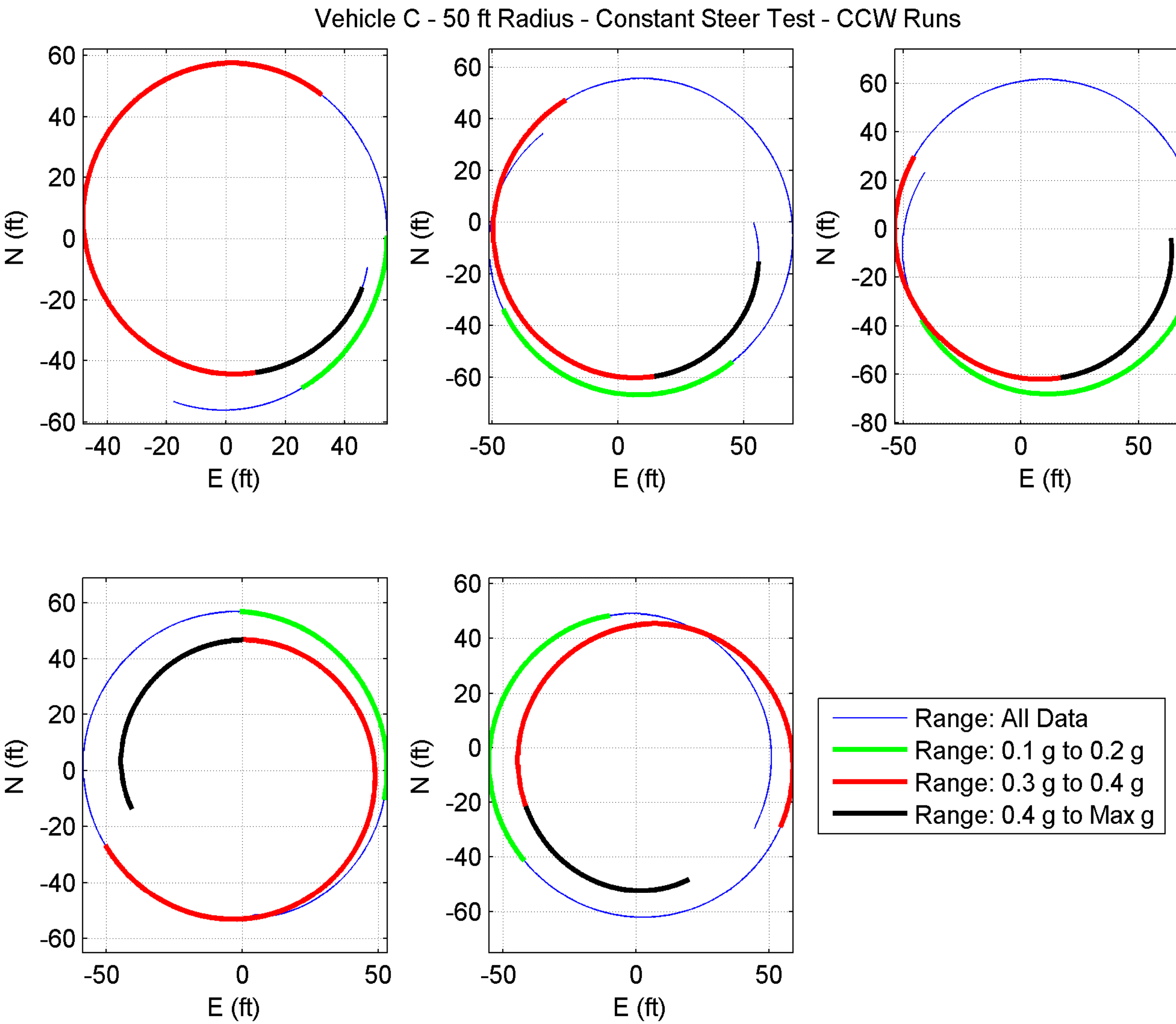

Vehicle C - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 4.31
Final Slope: 9.6
Ratio: 3.7
Final Slope: 7.8
Ratio: 1.47
Final Slope: 2.81
Ratio: 5.42
Final Slope: 11.7
Ratio: 2.72
Final Slope: 5.52



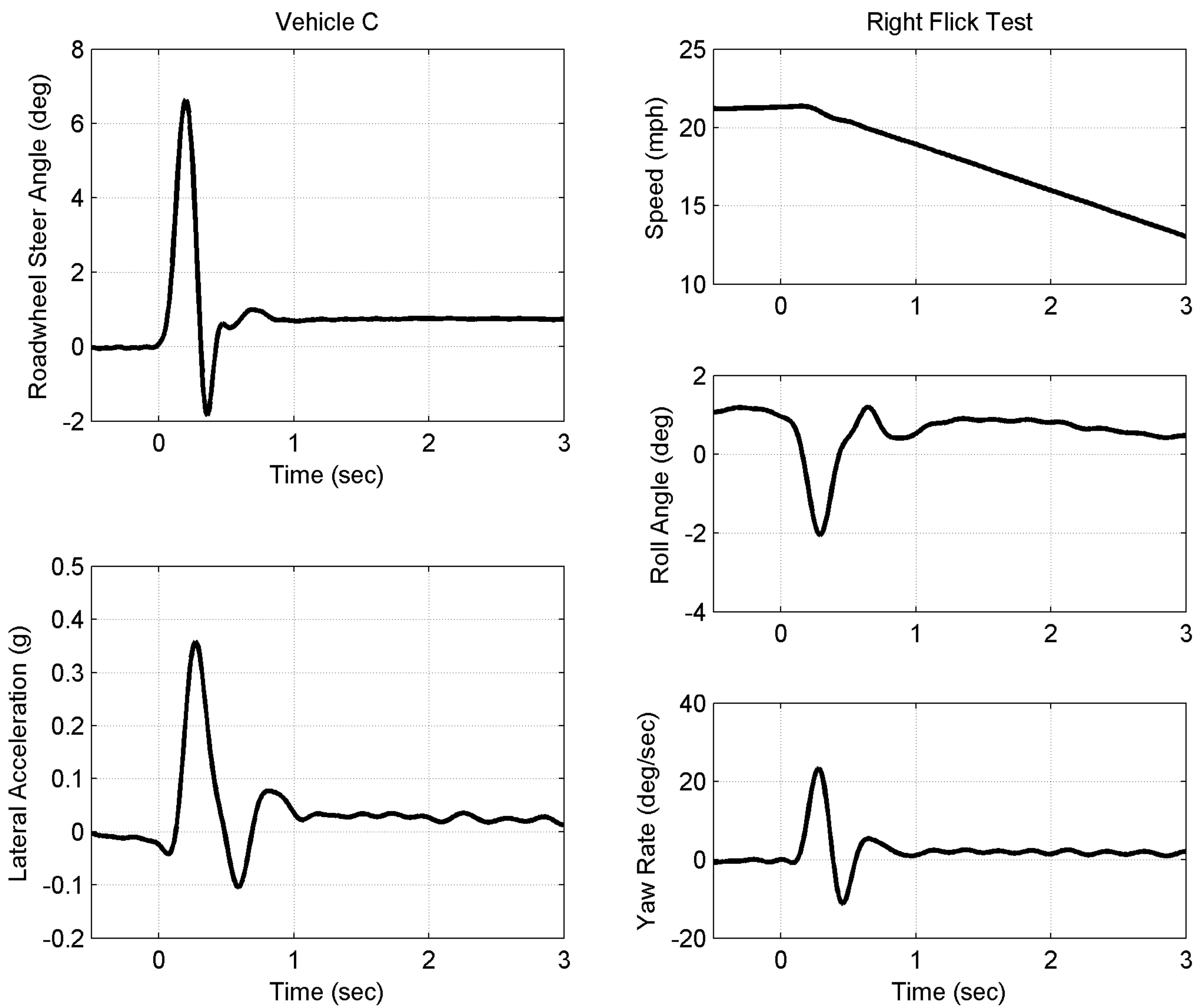
Vehicle C - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -3.82
Ratio: 1.38
Final Slope: -9.13
Ratio: 3.83
Final Slope: -4.34
Ratio: 1.85
Final Slope: -21.7
Ratio: 6.78
Final Slope: -8.25
Ratio: 2.92
Yaw Rate (deg/sec)
Speed (m/s)
-15
-20
-25
-30
6
7
8
9

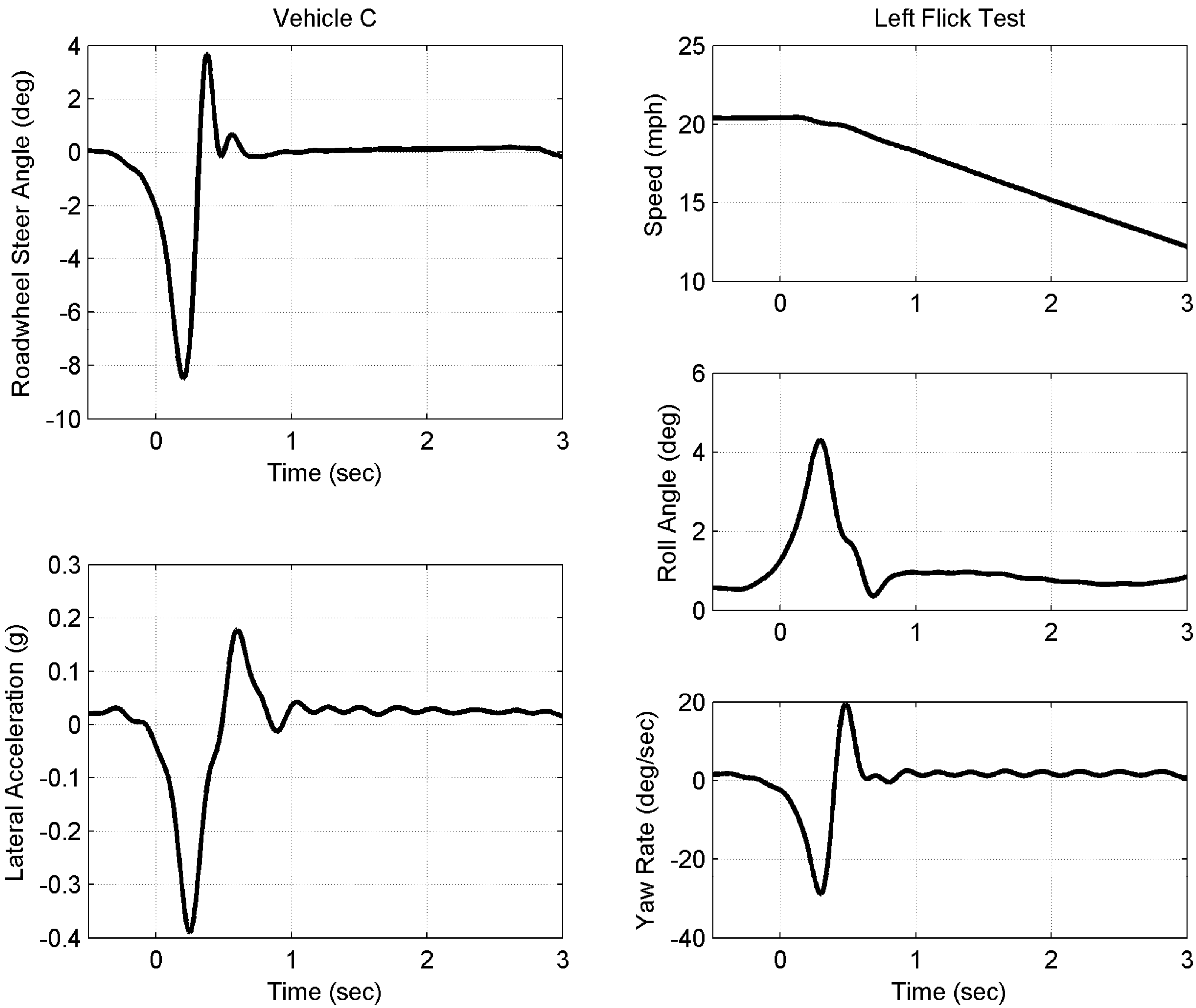


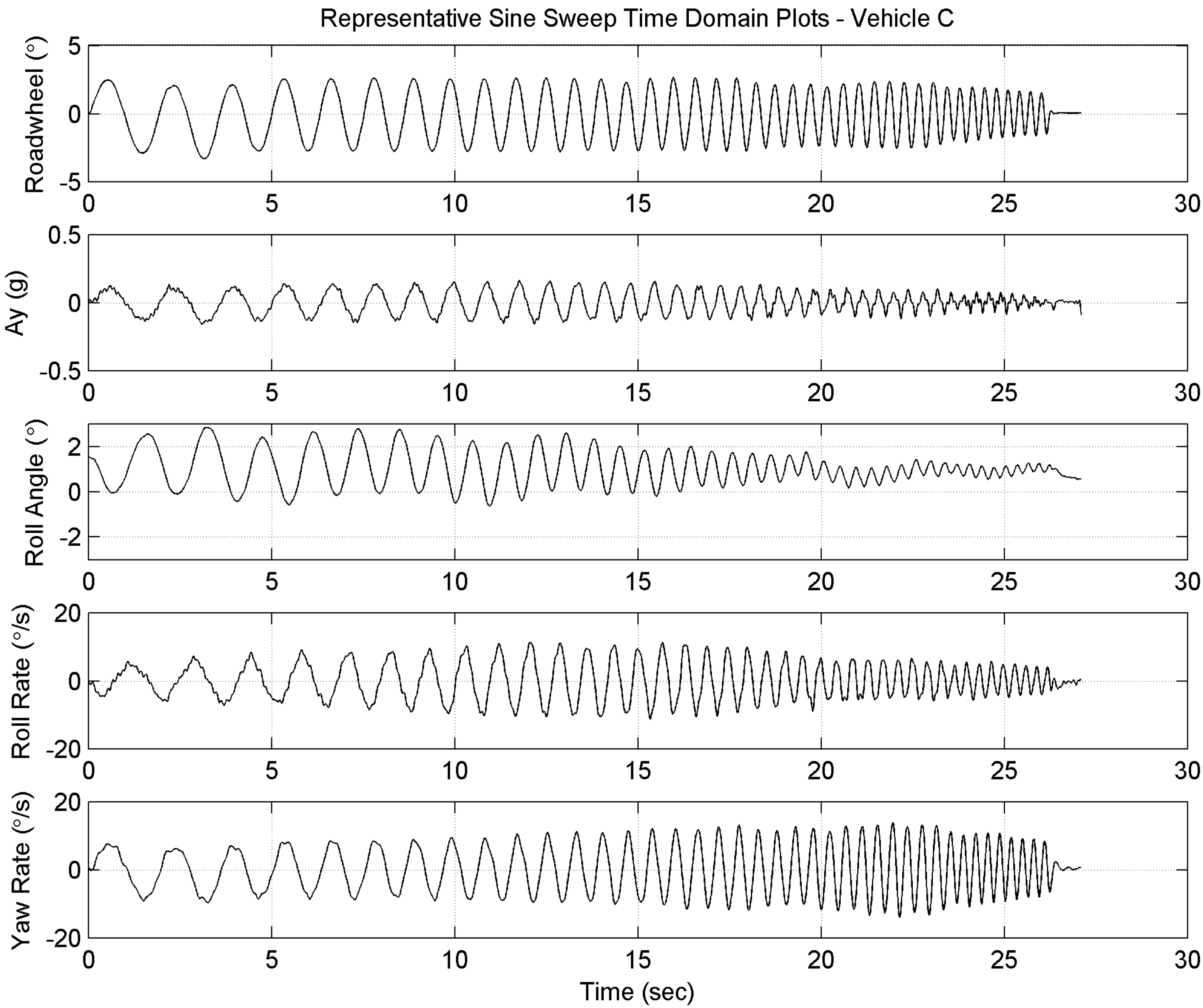
Vehicle C - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
80
60
40
20
0
-20
-40
-60
-80
-50
0
50
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g



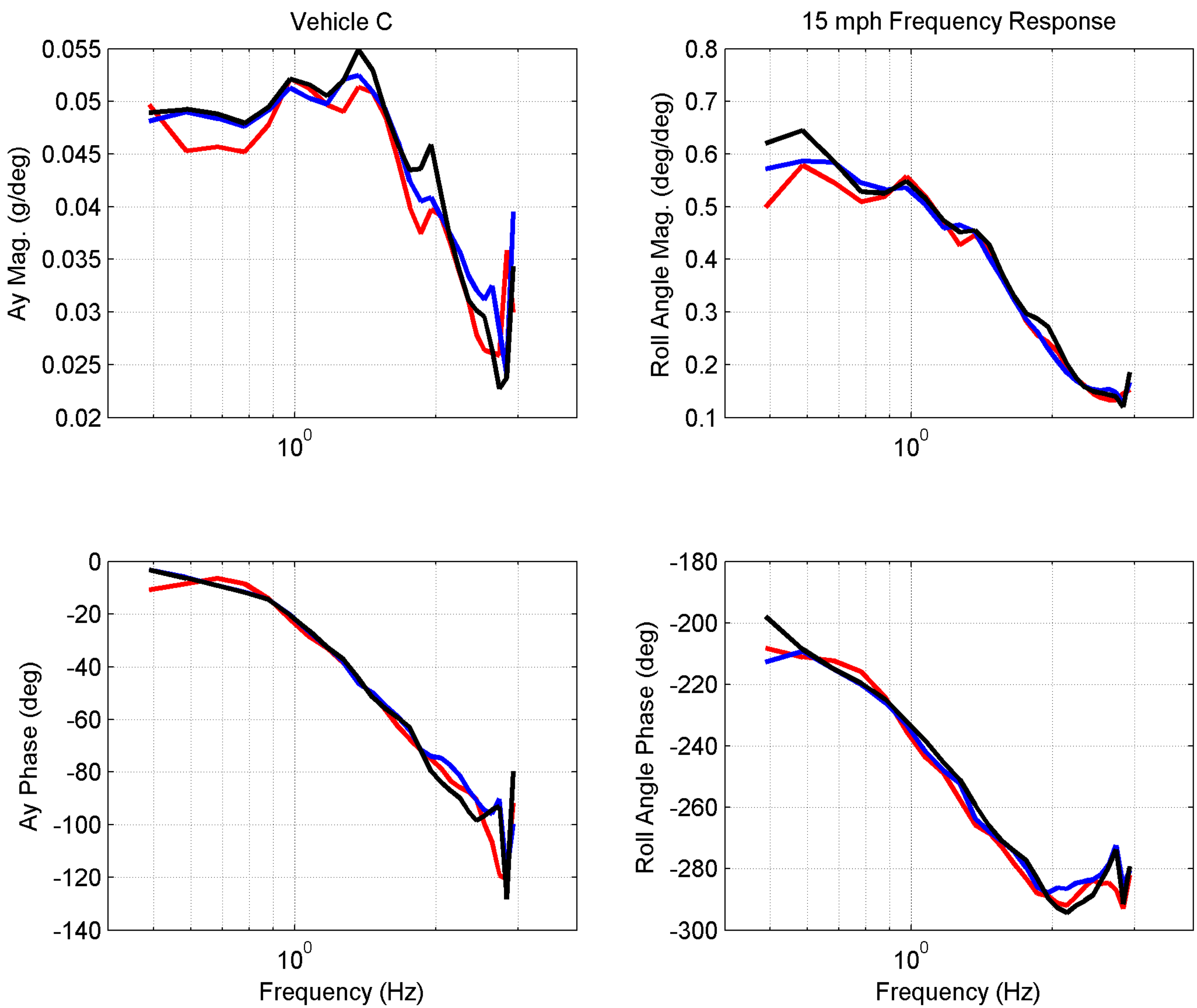
Vehicle C - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g


Vehicle C
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

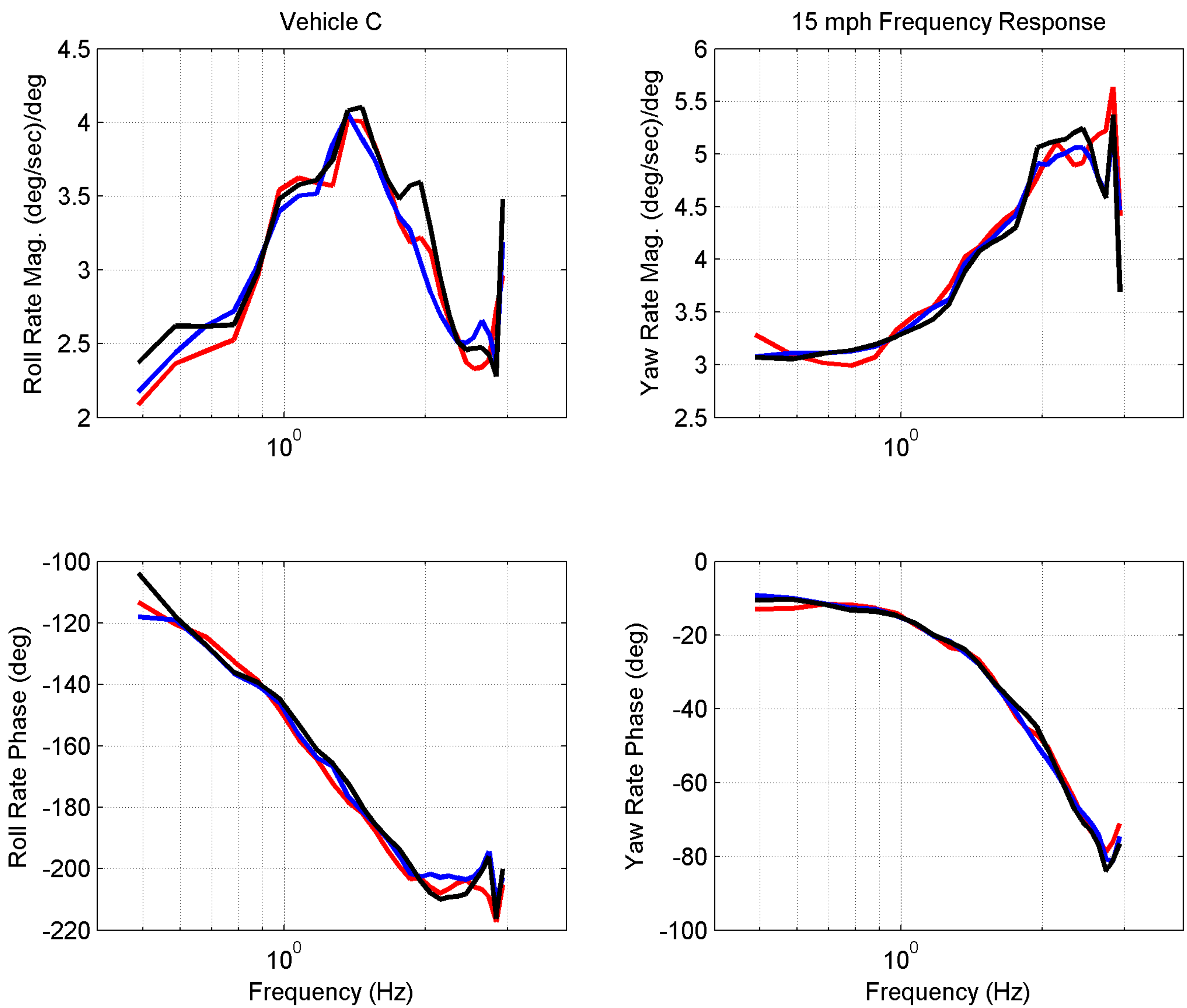

Vehicle C
Left Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

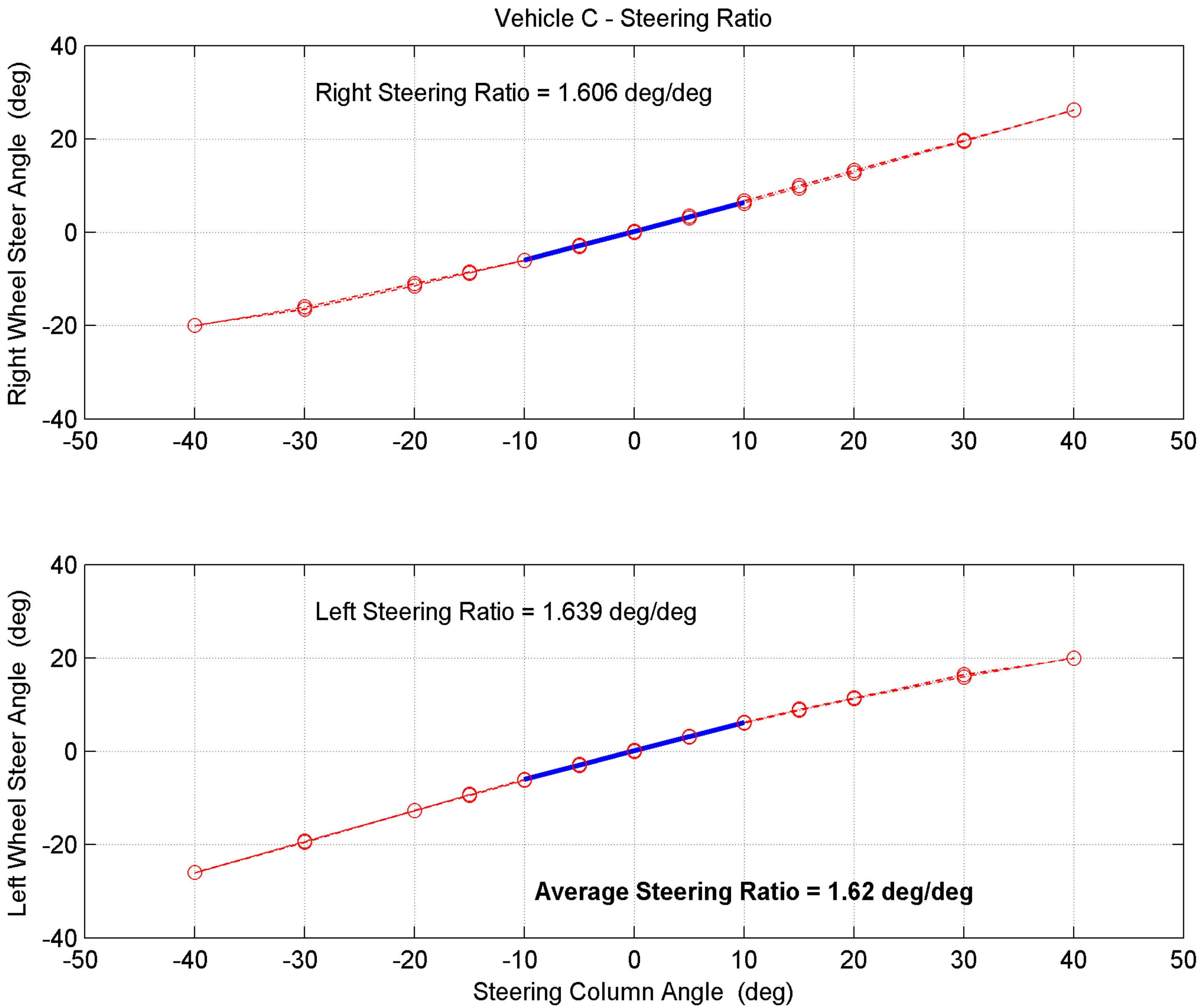


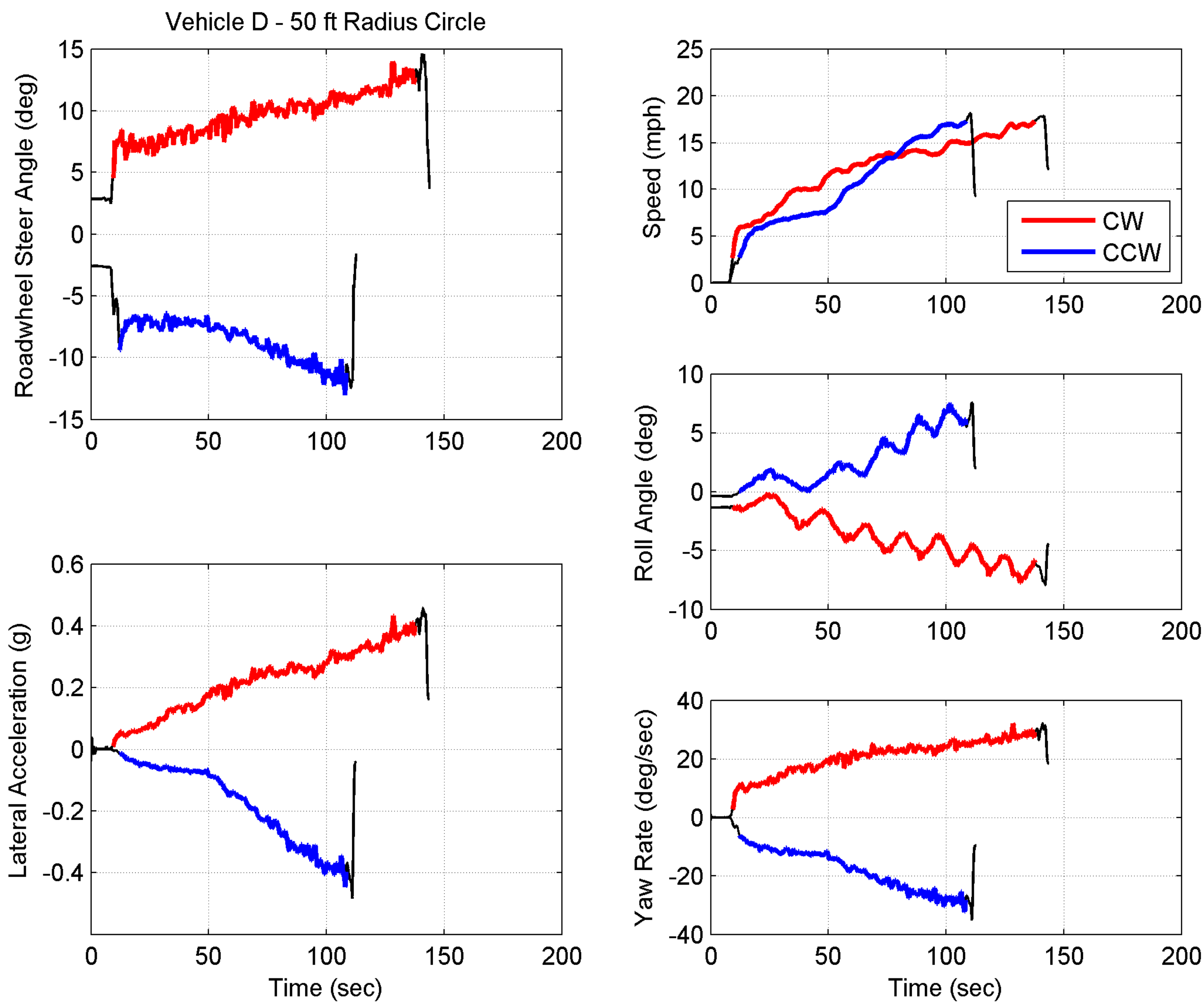
Representative Sine Sweep Time Domain Plots - Vehicle C
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

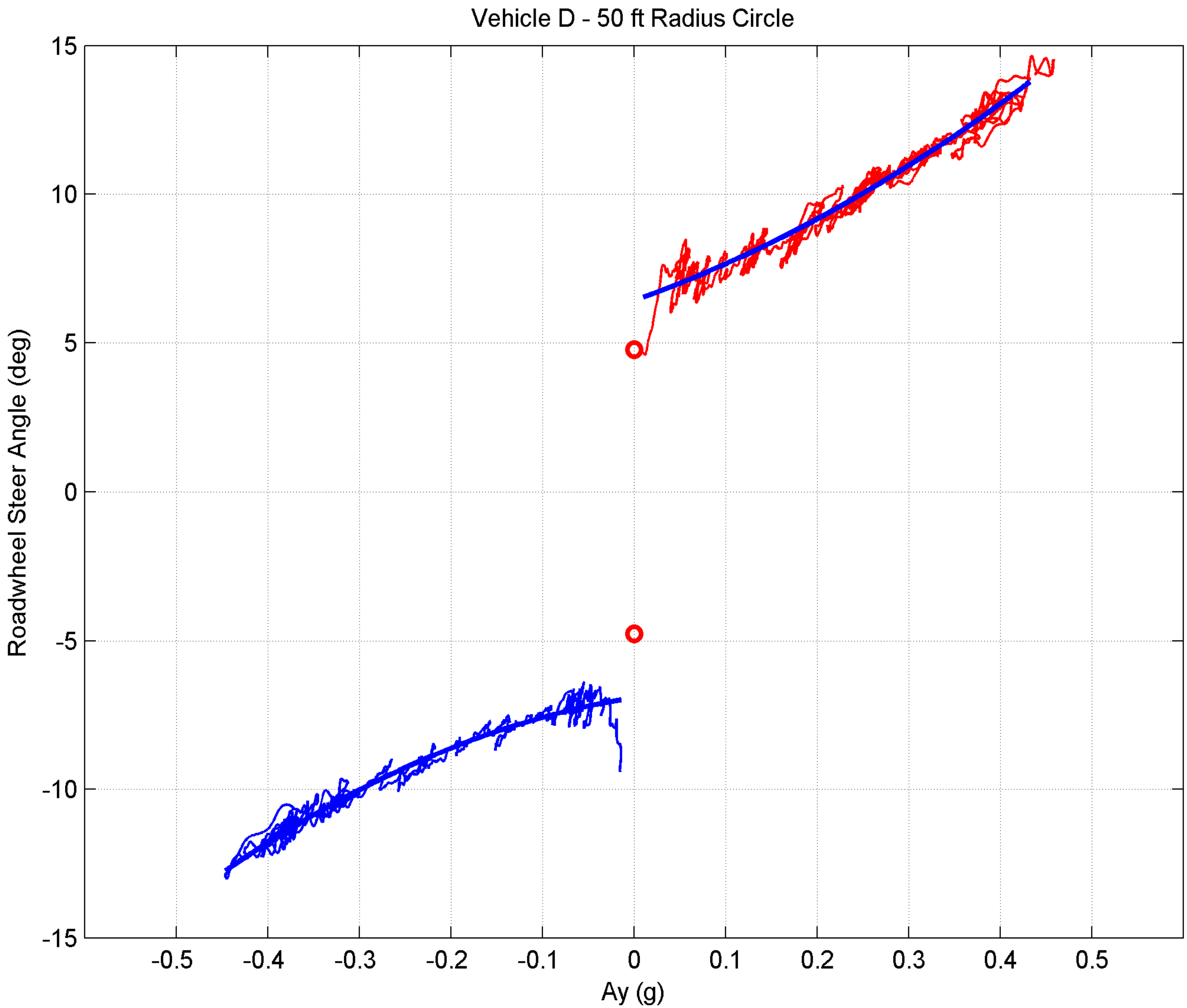


Vehicle C
15 mph Frequency Response
Ay Mag. (g/deg)
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
Roll Angle Mag. (deg/deg)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Ay Phase (deg)
0
-20
-40
-60
-80
-100
-120
-140
Roll Angle Phase (deg)
-180
-200
-220
-240
-260
-280
-300
10^0
Frequency (Hz)

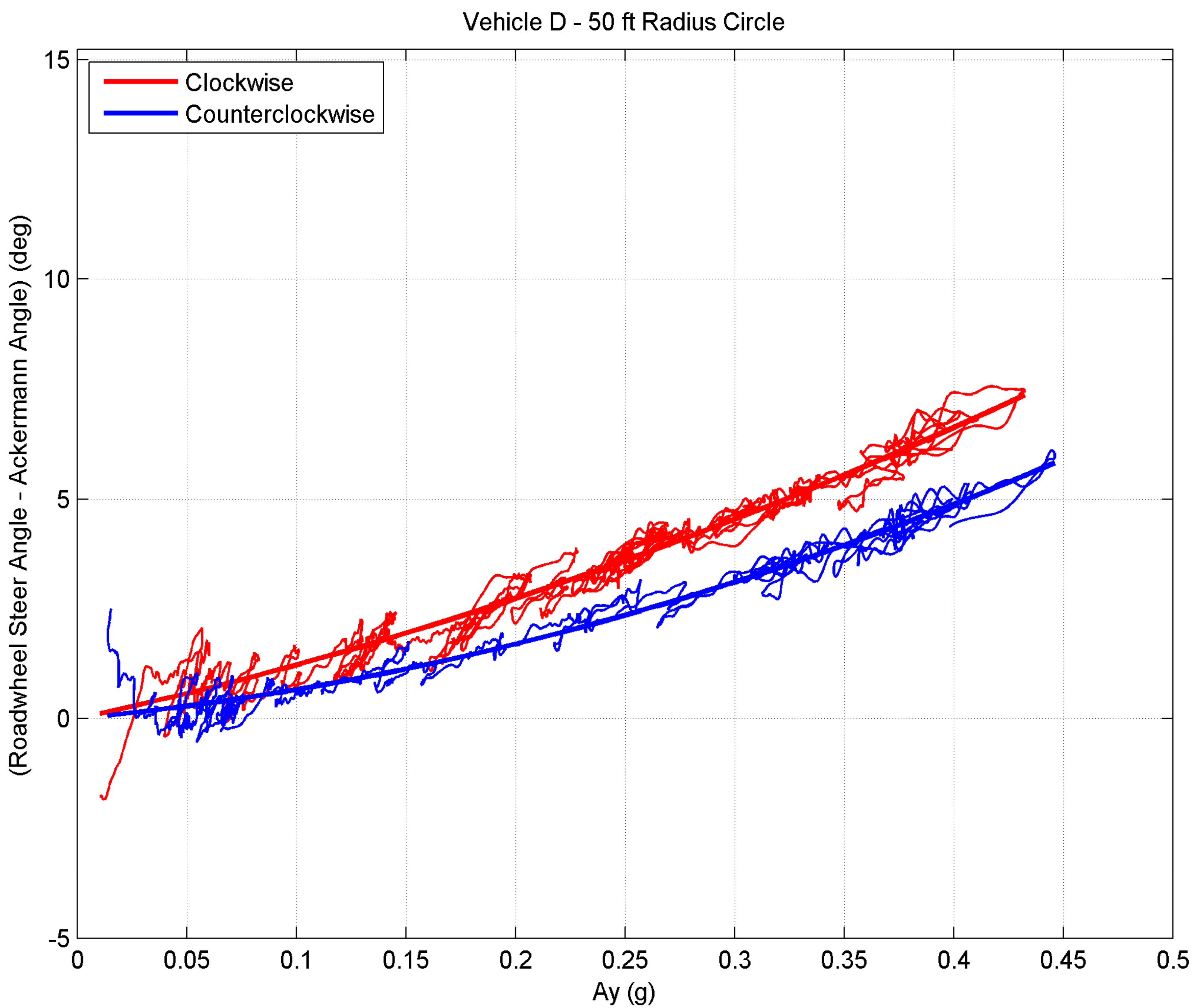

Vehicle C
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
4.5
4
3.5
3
2.5
2
6
5.5
5
4.5
4
3.5
3
2.5
-100
-120
-140
-160
-180
-200
-220
0
-20
-40
-60
-80
-100
10^0
Frequency (Hz)

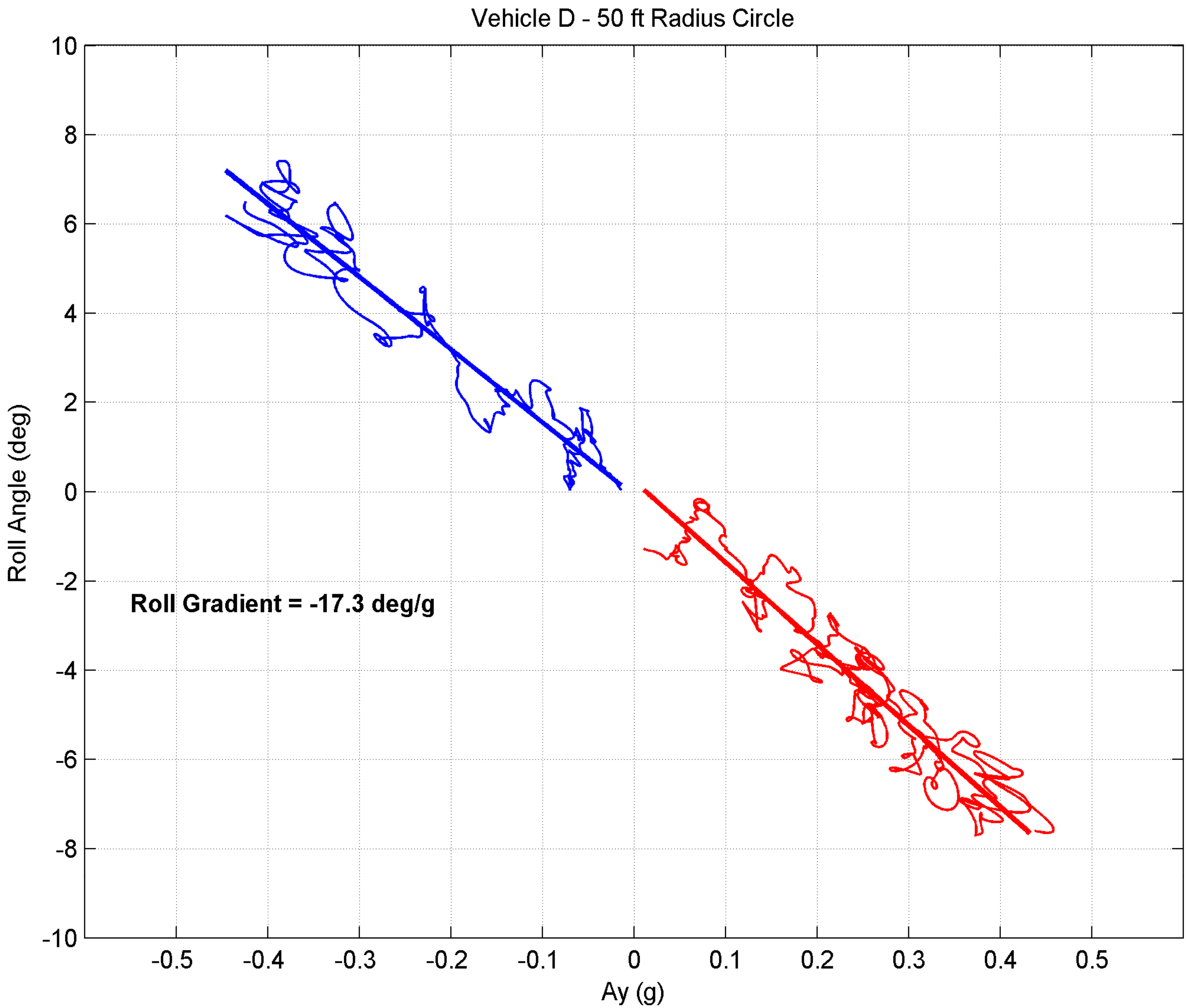

Vehicle C - Steering Ratio
Right Steering Ratio = 1.606 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-50
-40
-30
-20
-10
0
10
20
30
40
50
Left Steering Ratio = 1.639 deg/deg
Left Wheel Steer Angle (deg)
Average Steering Ratio = 1.62 deg/deg
Steering Column Angle (deg)


Vehicle D - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

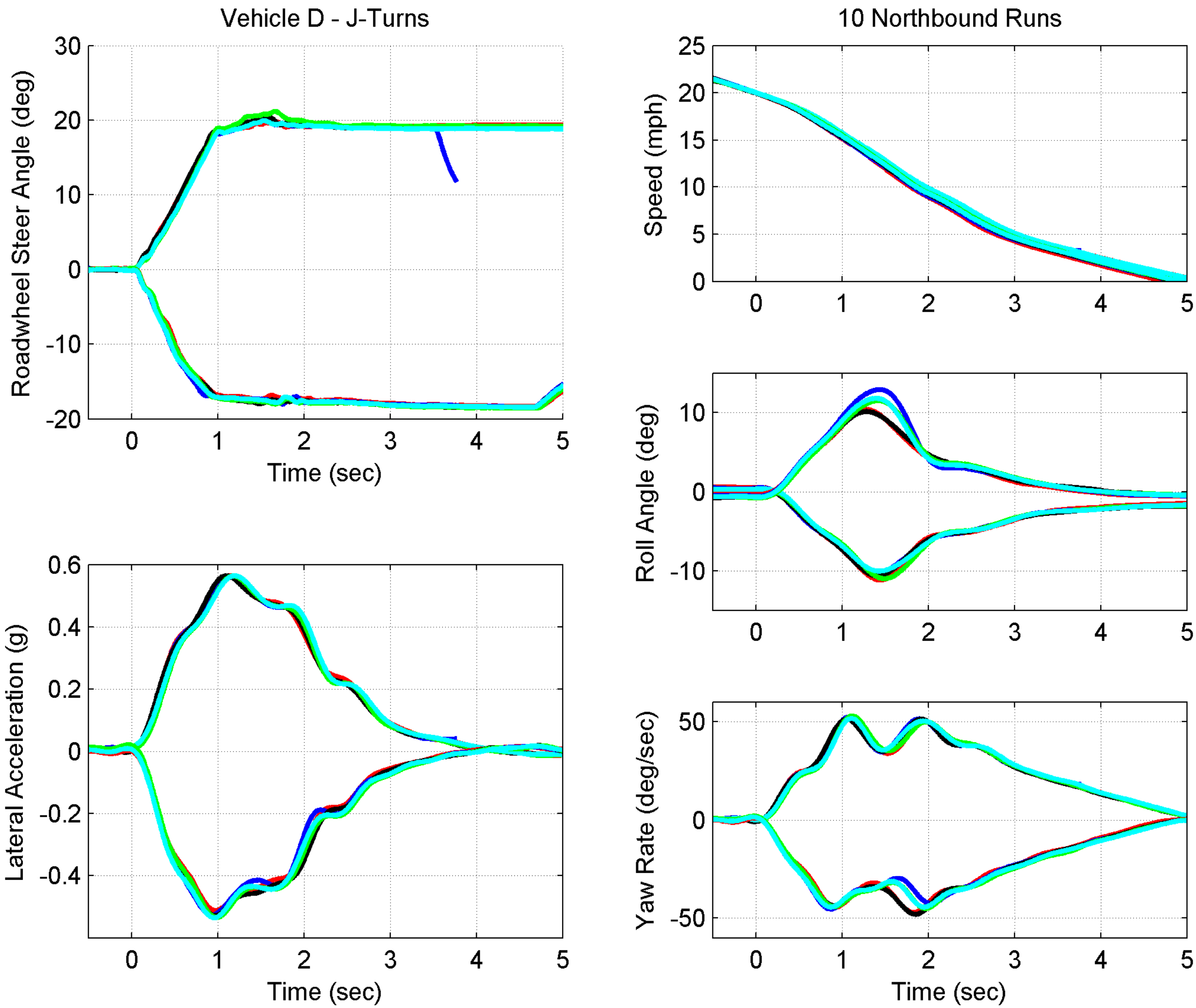


Vehicle D - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

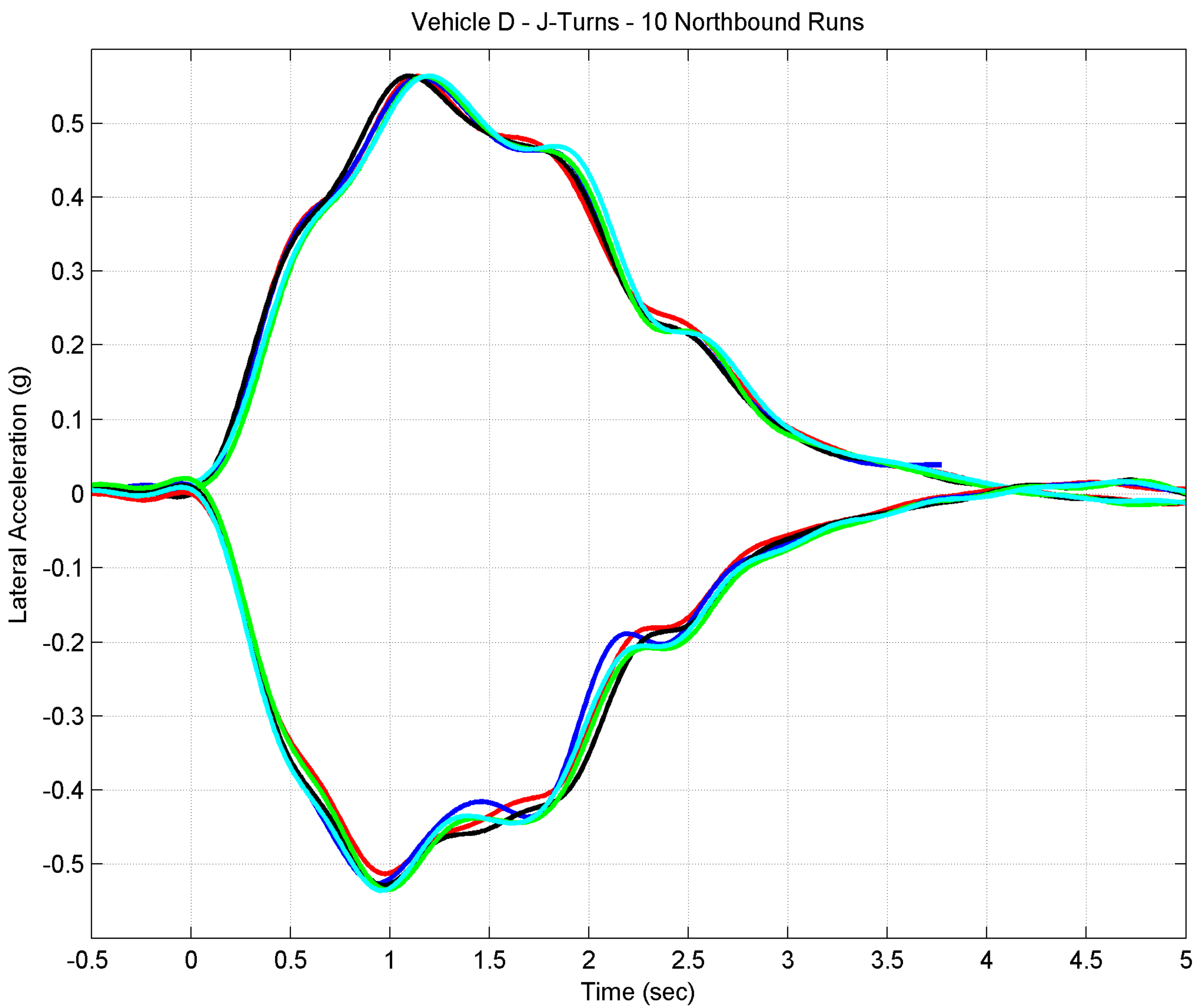

Vehicle D - 50 ft Radius Circle
Clockwise
Counterclockwise
(Roadwheel Steer Angle - Ackermann Angle) (deg)
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Ay (g)



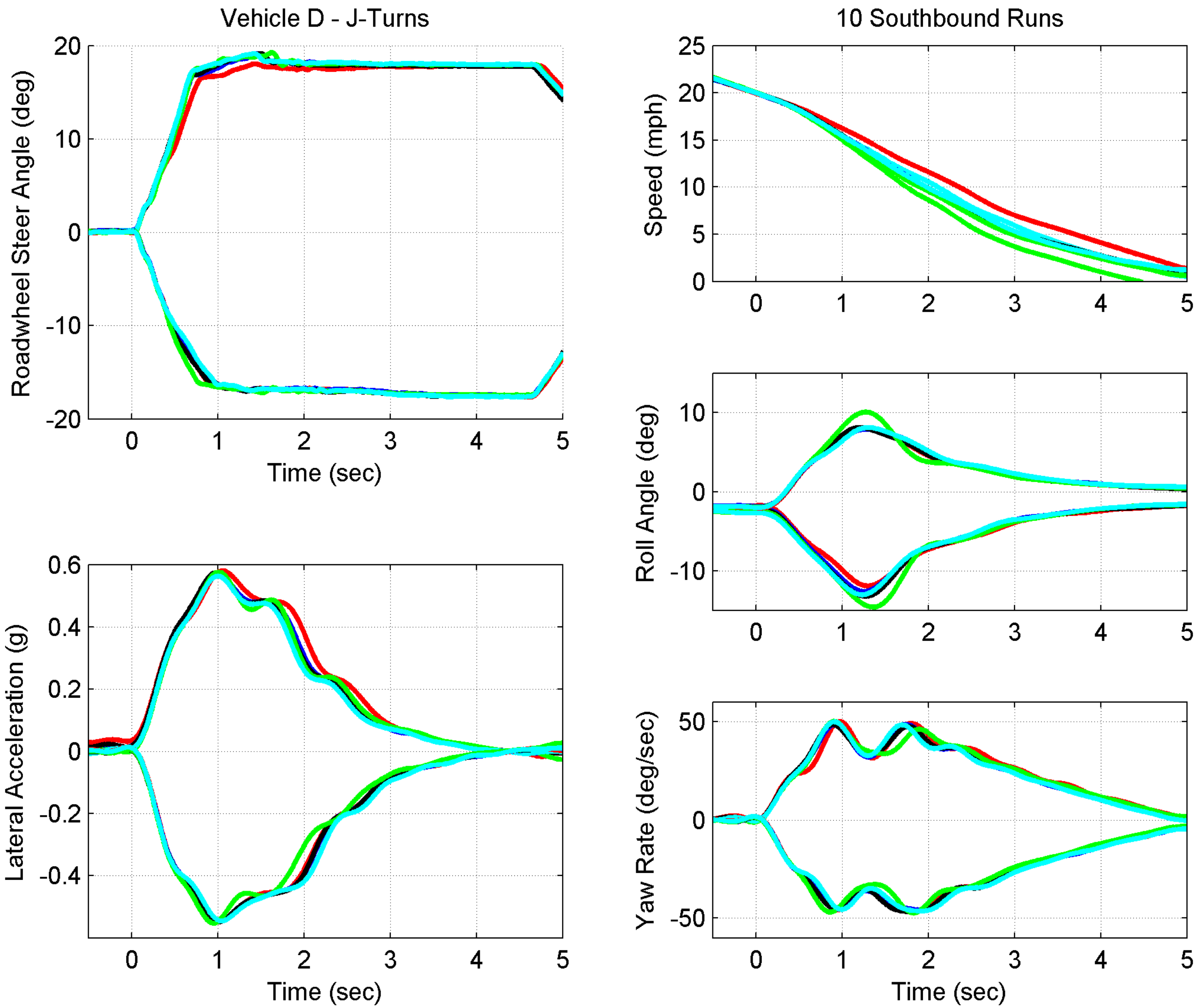
Vehicle D - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Roll Gradient = -17.3 deg/g



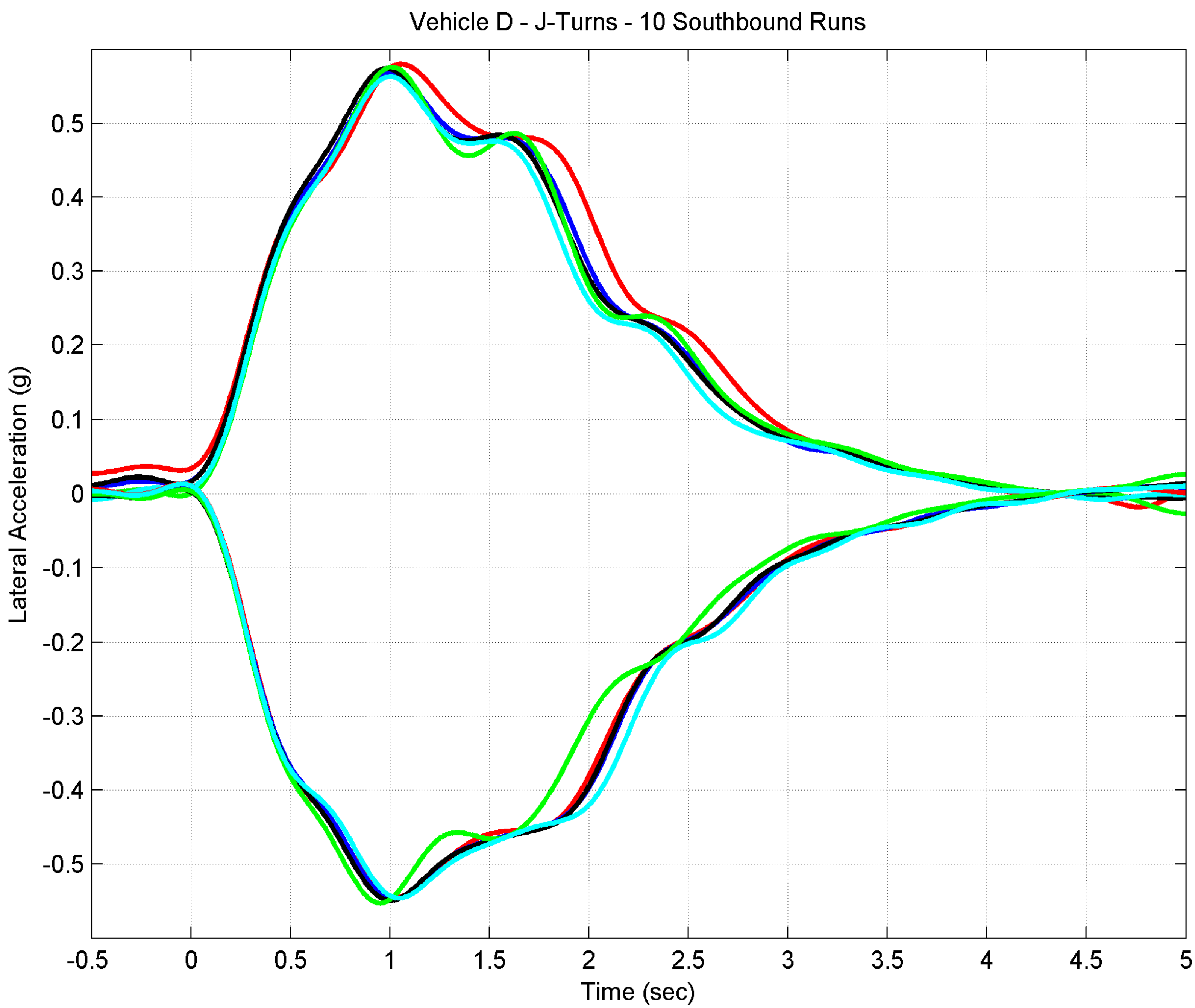
Vehicle D - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



Vehicle D - J-Turns - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle D - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



Vehicle D - J-Turns - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle D

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.5635	-0.5129
2	0.5615	-0.5264
3	0.5638	-0.5294
4	0.5631	-0.5353
5	0.5639	-0.5361
Mean Value of 5 Runs	0.5631	-0.5280
Standard Deviation of 5 Runs	0.001	0.009

Average of 10 Northbound Runs

0.5456

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.5798	-0.5449
2	0.5689	-0.5479
3	0.5741	-0.5494
4	0.5757	-0.5531
5	0.5630	-0.5462
Mean Value of 5 Runs	0.5723	-0.5483
Standard Deviation of 5 Runs	0.007	0.003

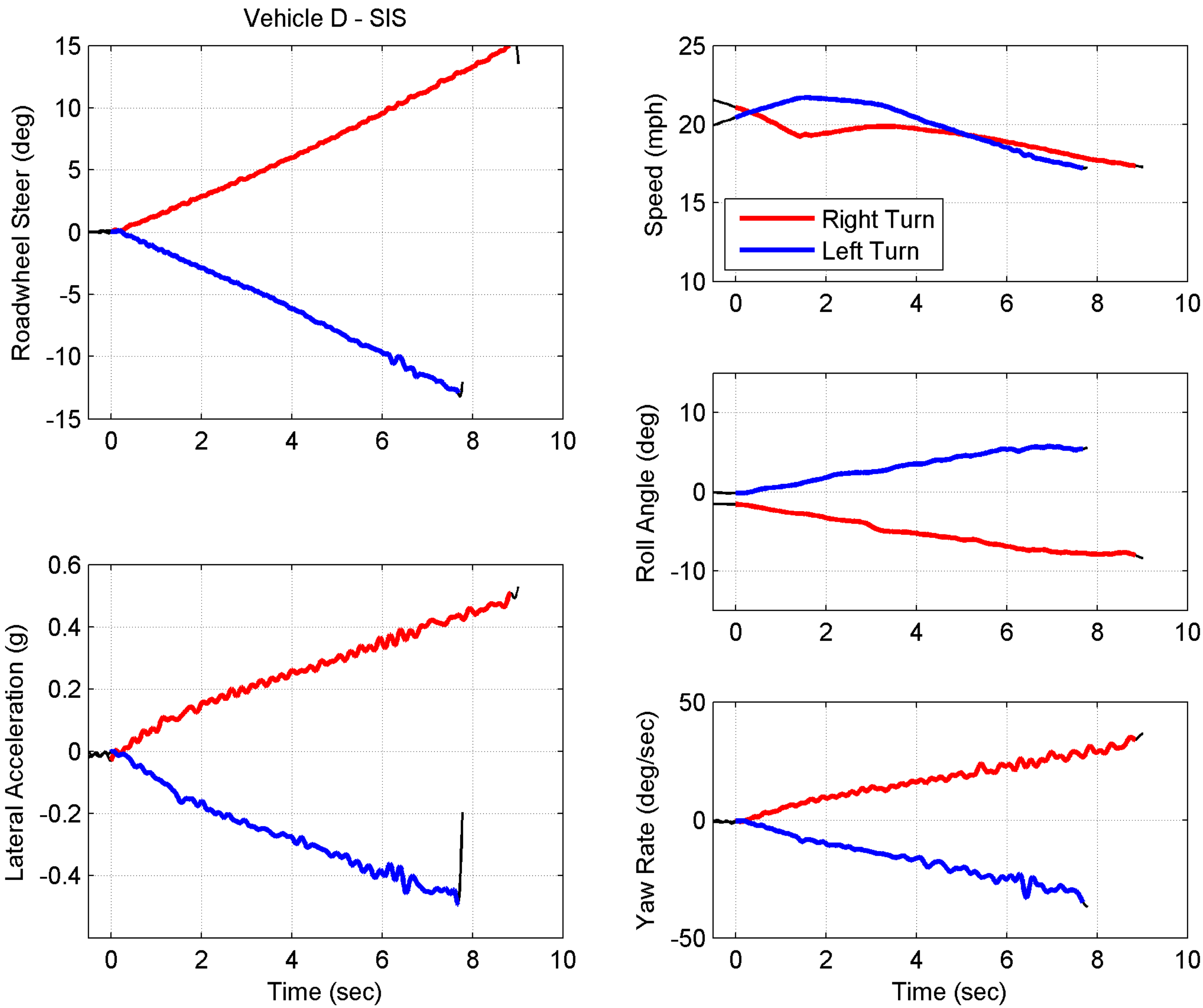
Average of 10 Southbound Runs

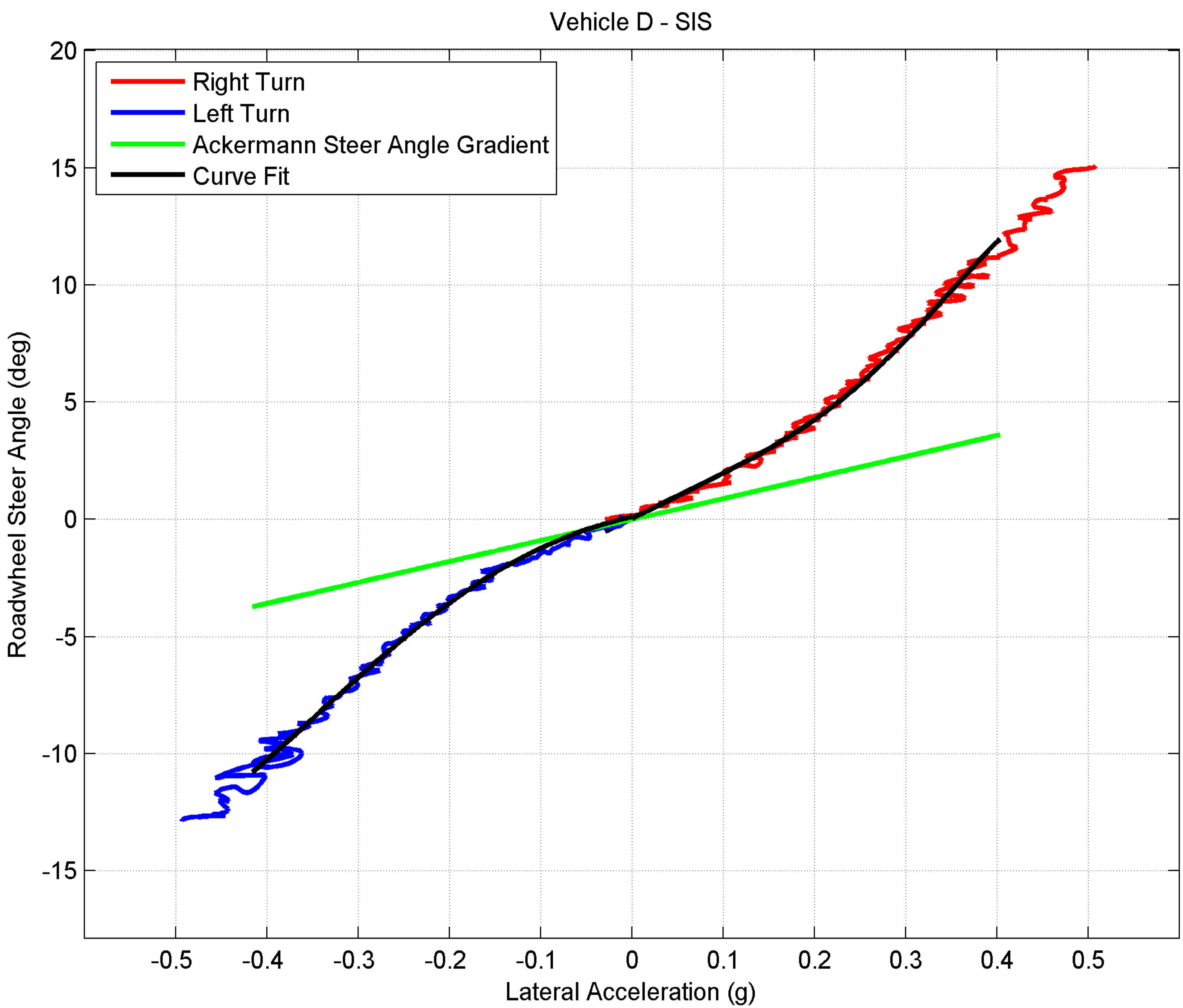
0.5603

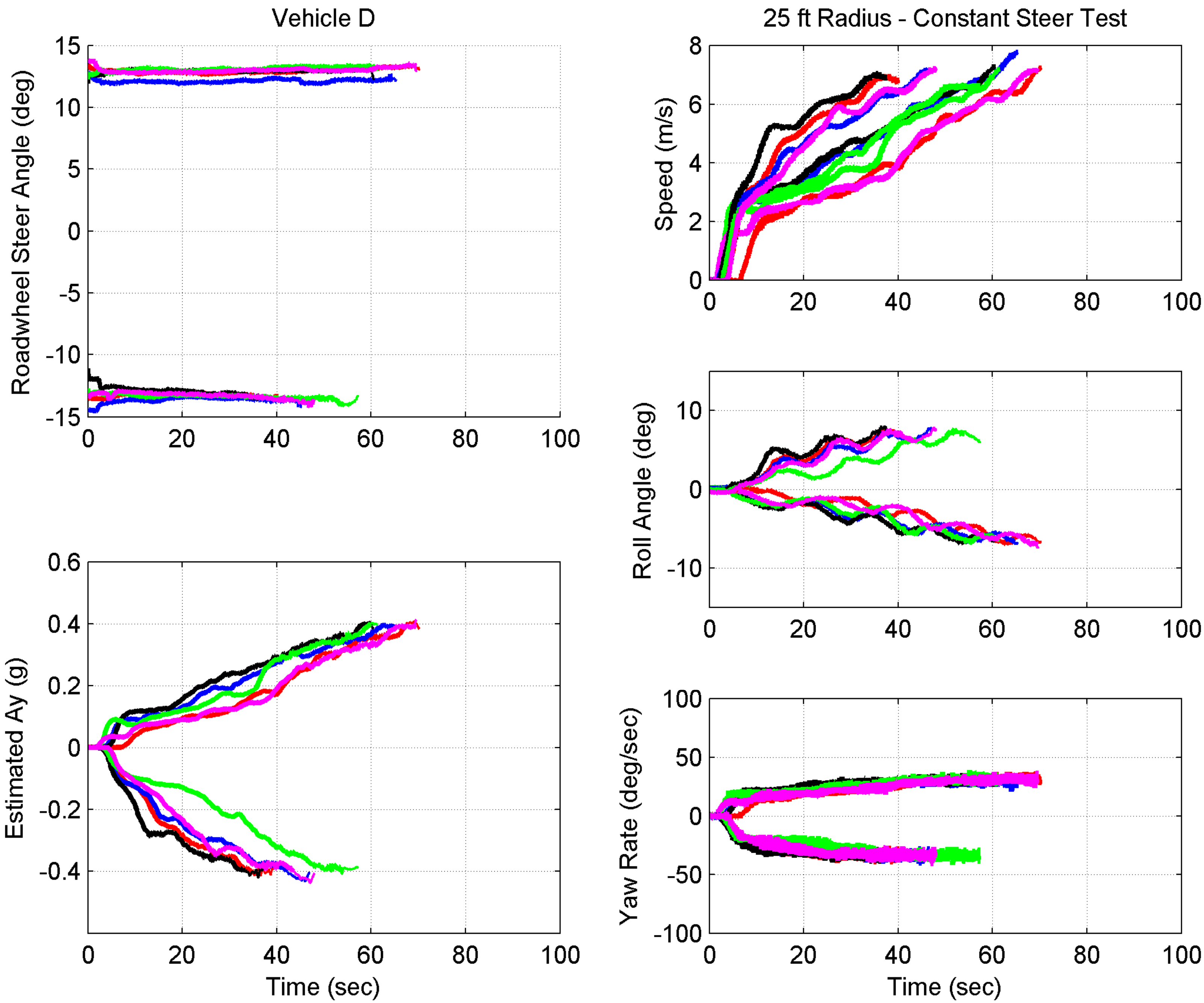
Average of All 20 Runs

0.553

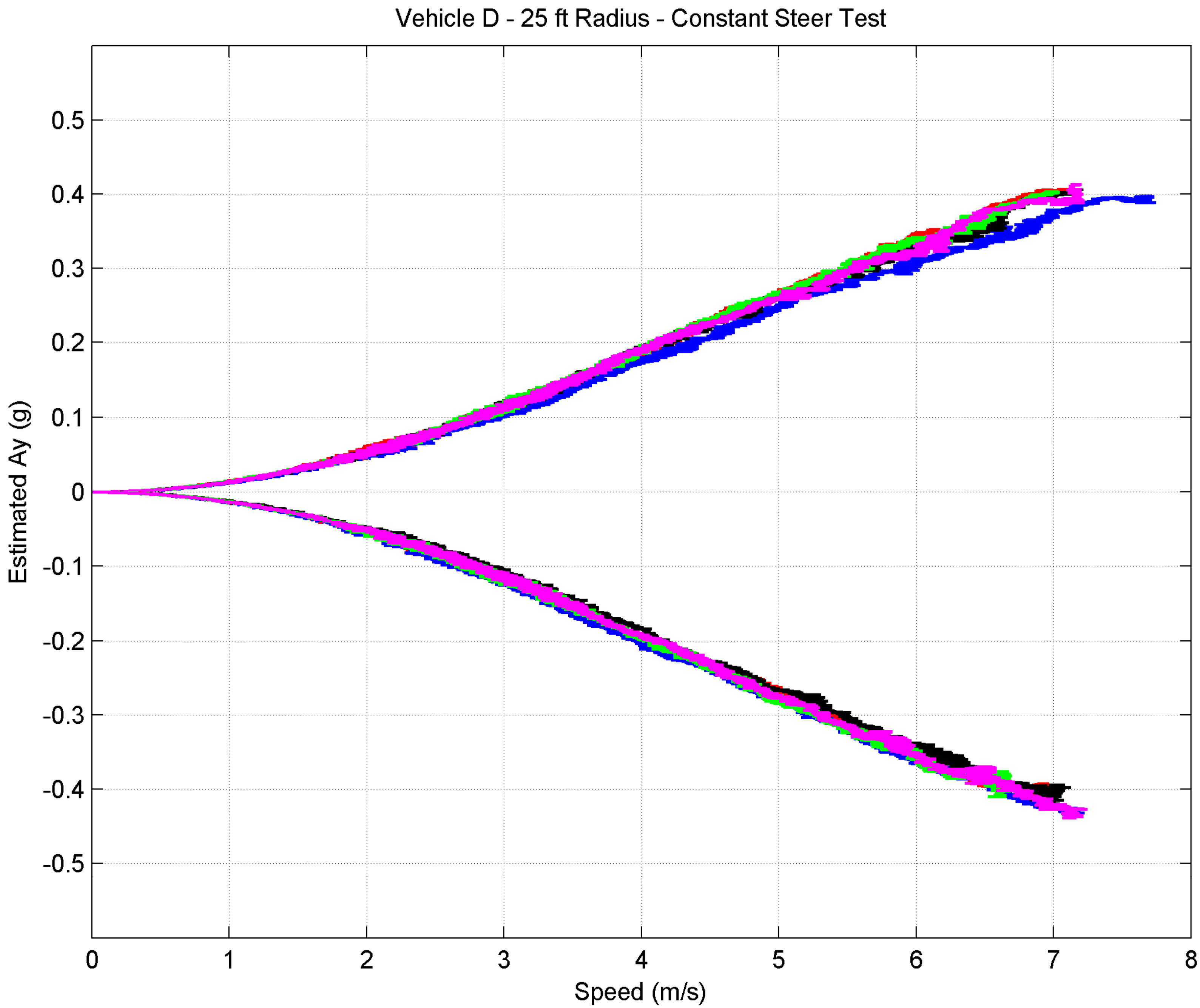
Threshold Ay


Vehicle D - SIS
Roadwheel Steer (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

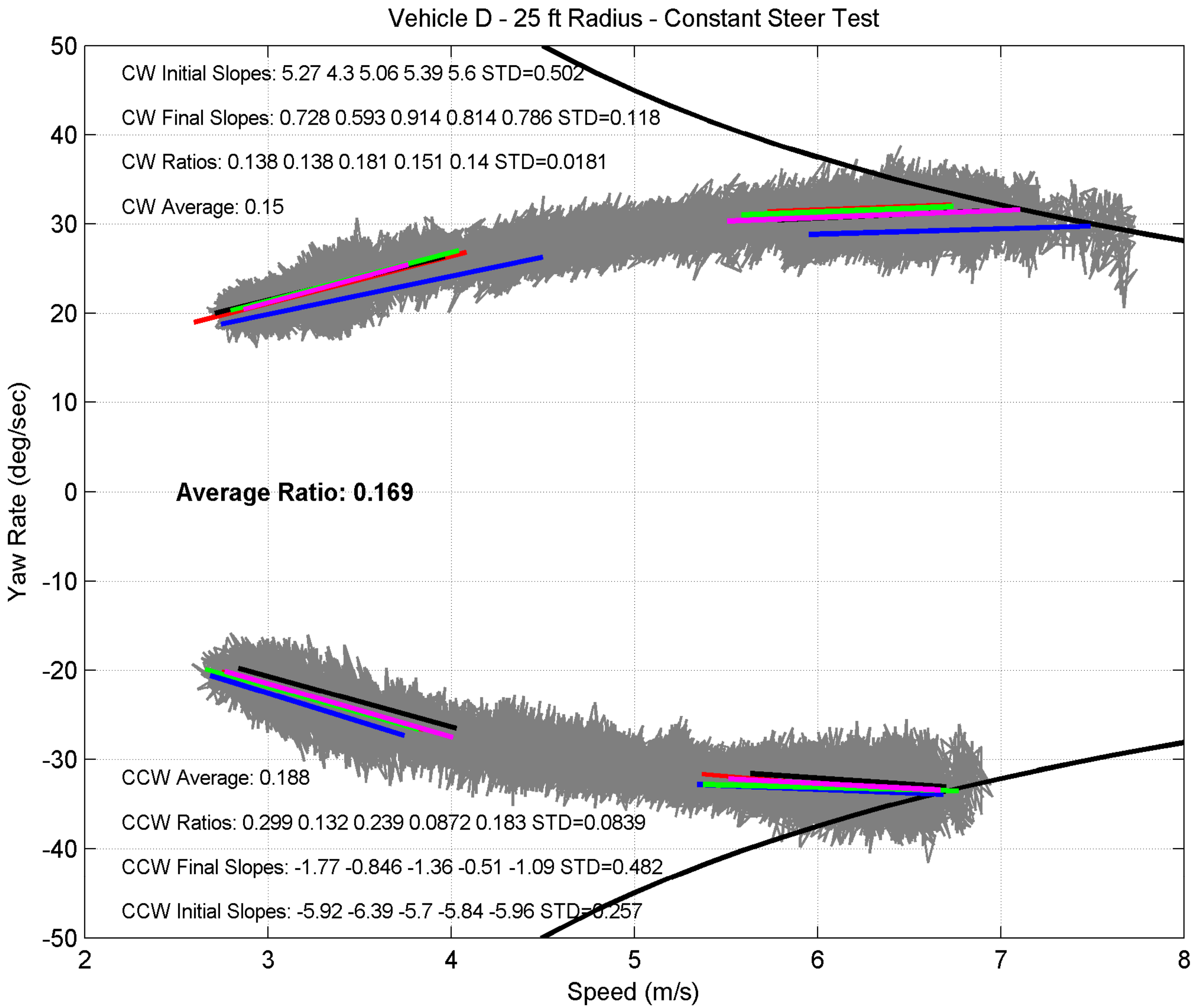

Vehicle D - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
20
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5



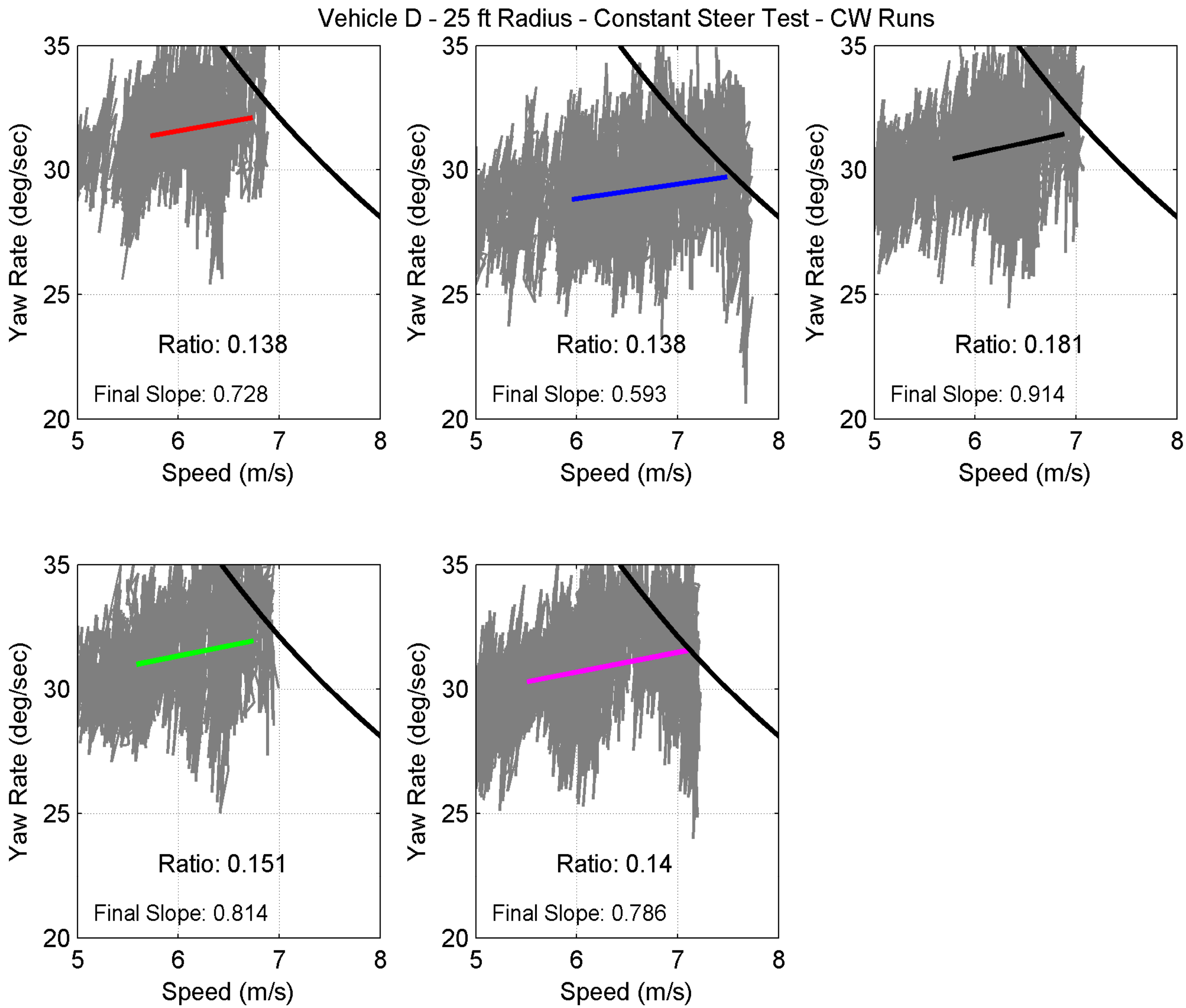
Vehicle D
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



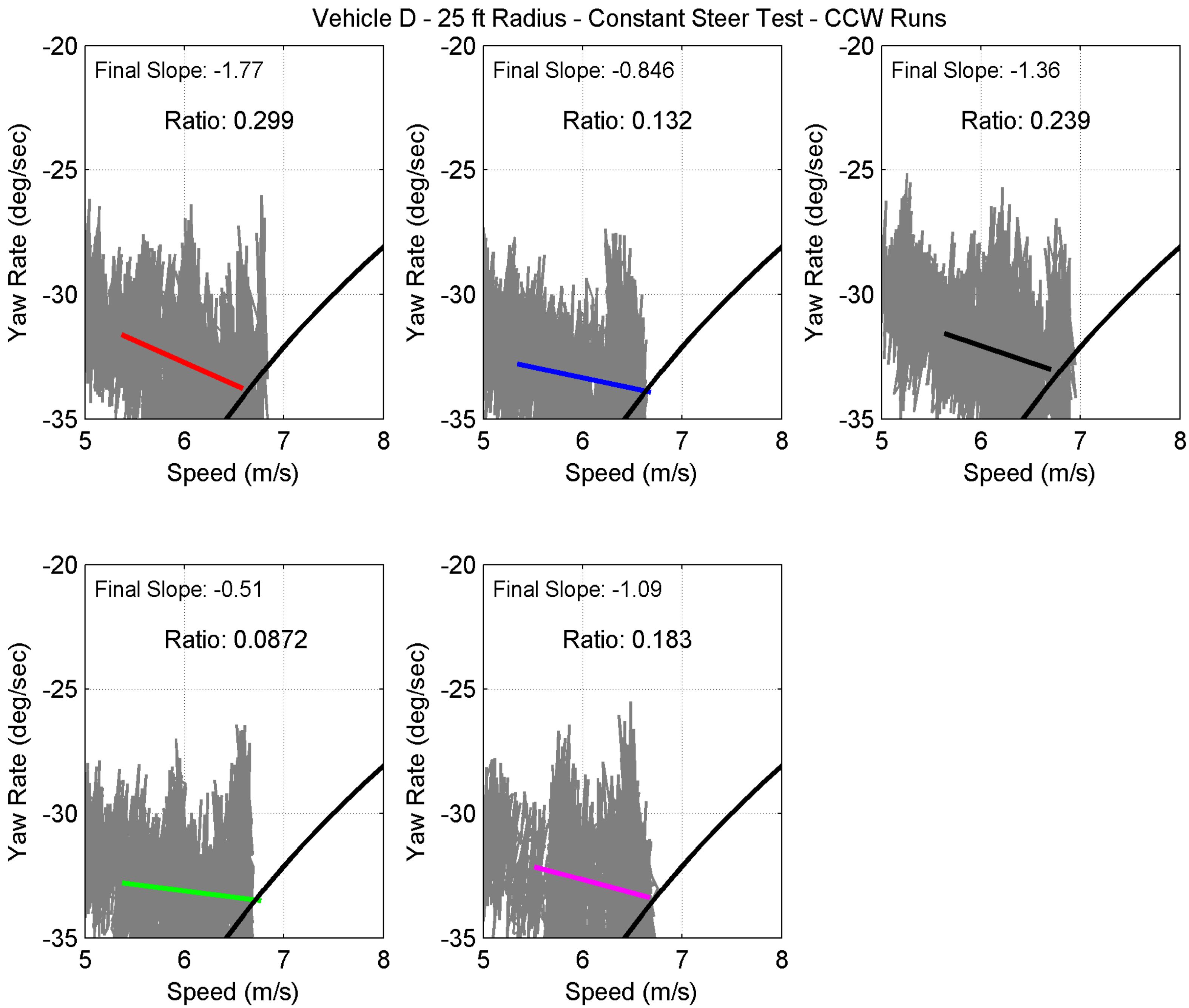
Vehicle D - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
Speed (m/s)



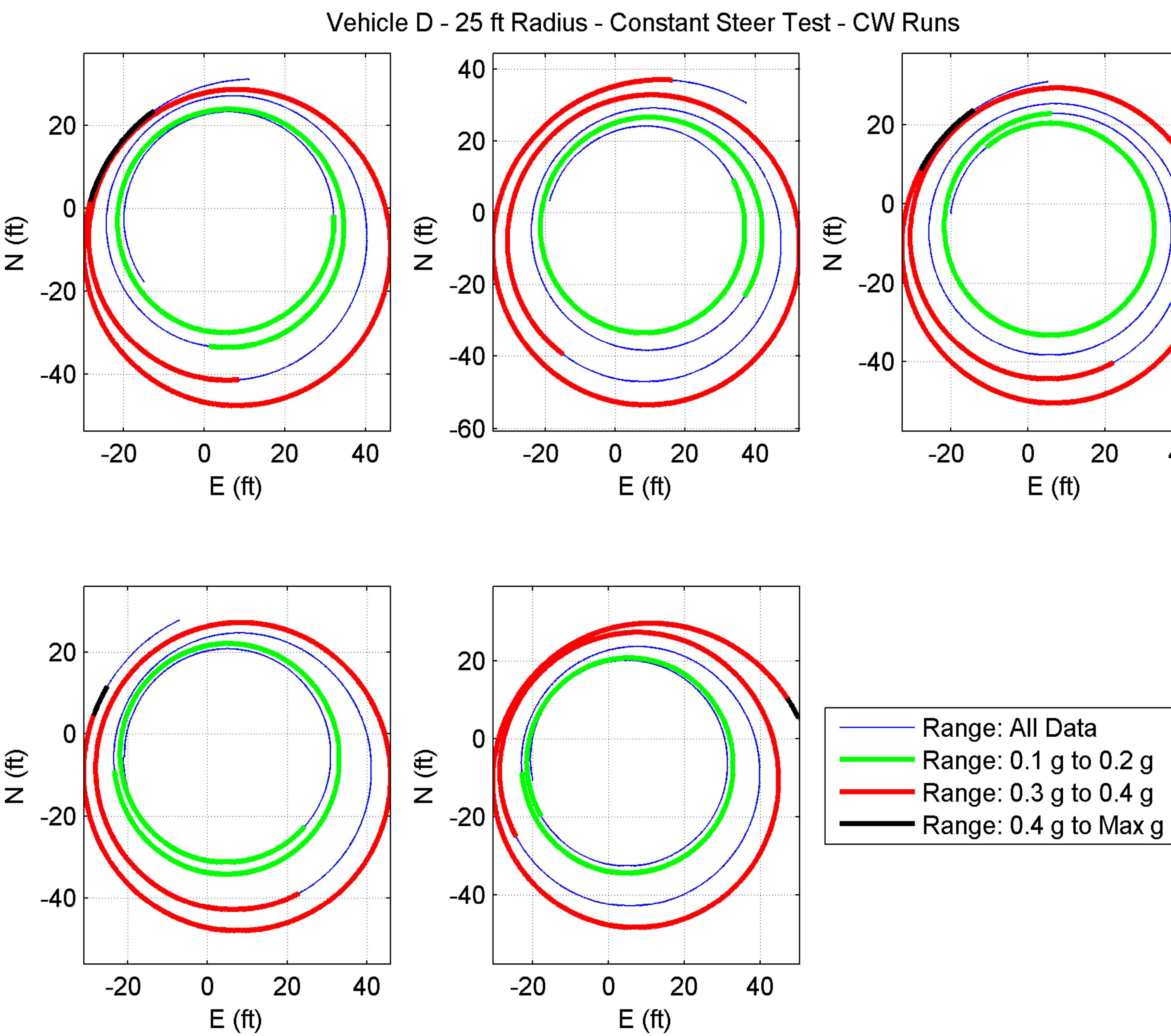
Vehicle D - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 5.27 4.3 5.06 5.39 5.6 STD=0.502
CW Final Slopes: 0.728 0.593 0.914 0.814 0.786 STD=0.118
CW Ratios: 0.138 0.138 0.181 0.151 0.14 STD=0.0181
CW Average: 0.15
Average Ratio: 0.169
CCW Average: 0.188
CCW Ratios: 0.299 0.132 0.239 0.0872 0.183 STD=0.0839
CCW Final Slopes: -1.77 -0.846 -1.36 -0.51 -1.09 STD=0.482
CCW Initial Slopes: -5.92 -6.39 -5.7 -5.84 -5.96 STD=0.257
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8

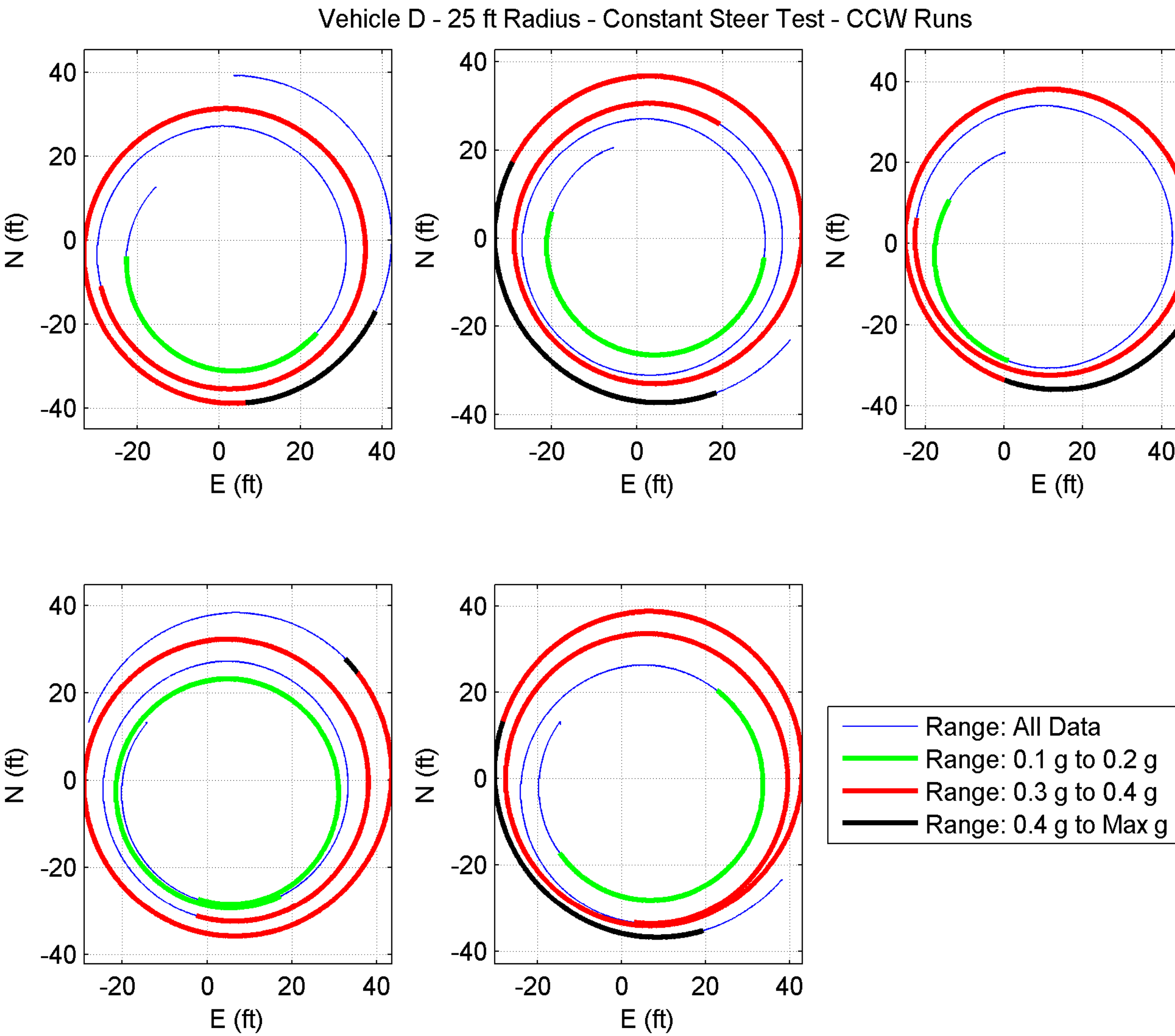


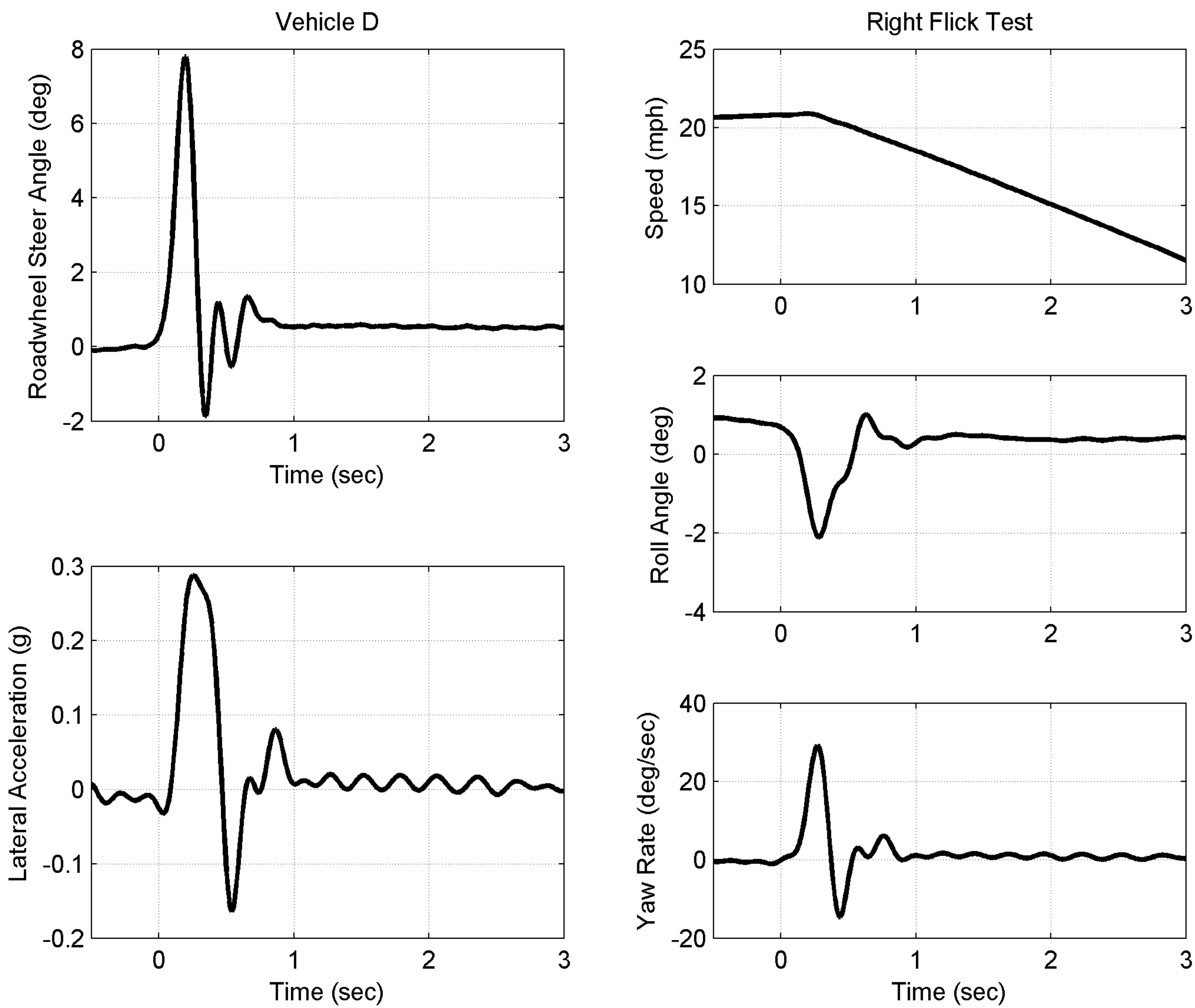
Vehicle D - 25 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 0.138
Final Slope: 0.728
Ratio: 0.138
Final Slope: 0.593
Ratio: 0.181
Final Slope: 0.914
Ratio: 0.151
Final Slope: 0.814
Ratio: 0.14
Final Slope: 0.786



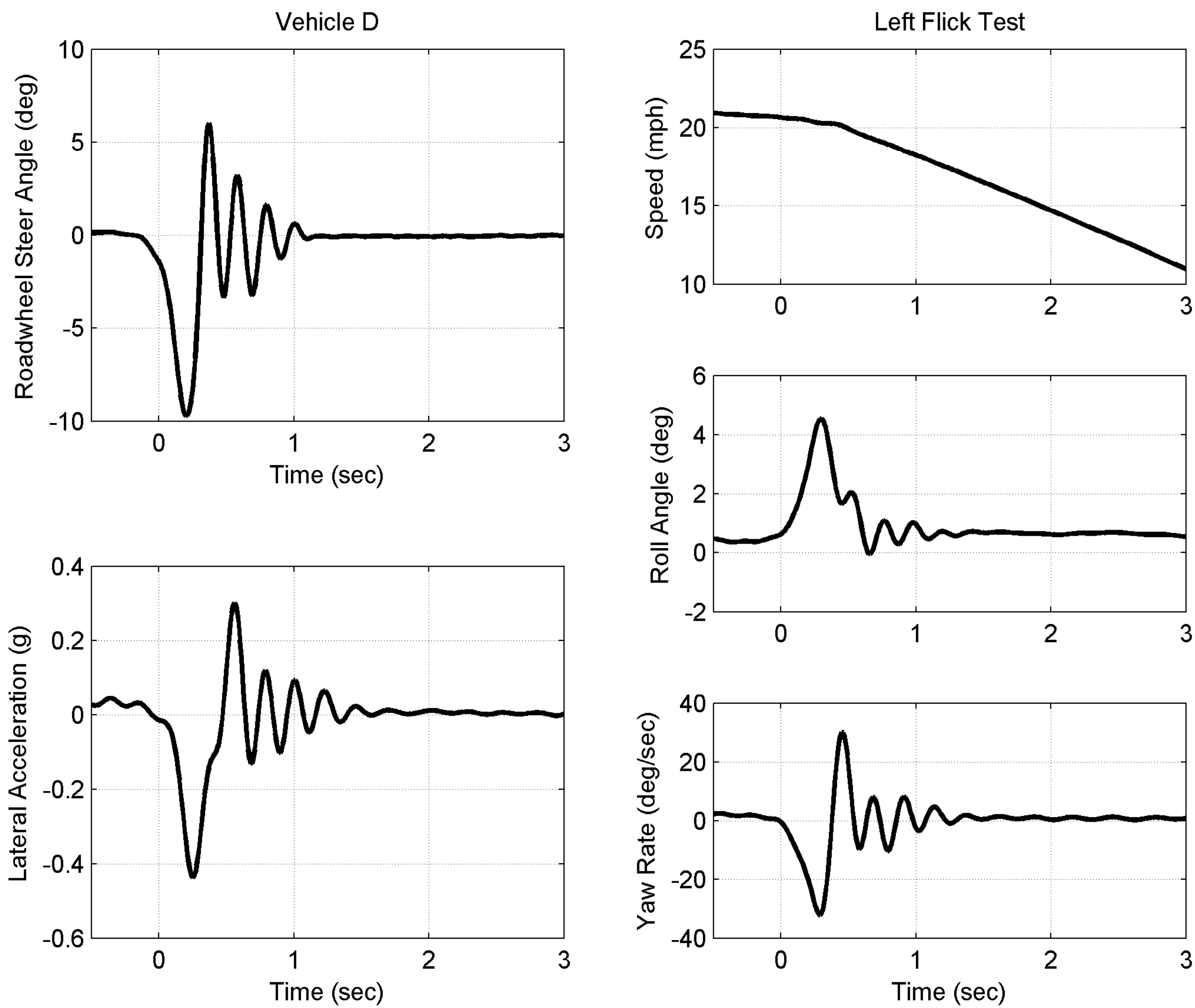
Vehicle D - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -1.77
Ratio: 0.299
Final Slope: -0.846
Ratio: 0.132
Final Slope: -1.36
Ratio: 0.239
Final Slope: -0.51
Ratio: 0.0872
Final Slope: -1.09
Ratio: 0.183
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
5
6
7
8

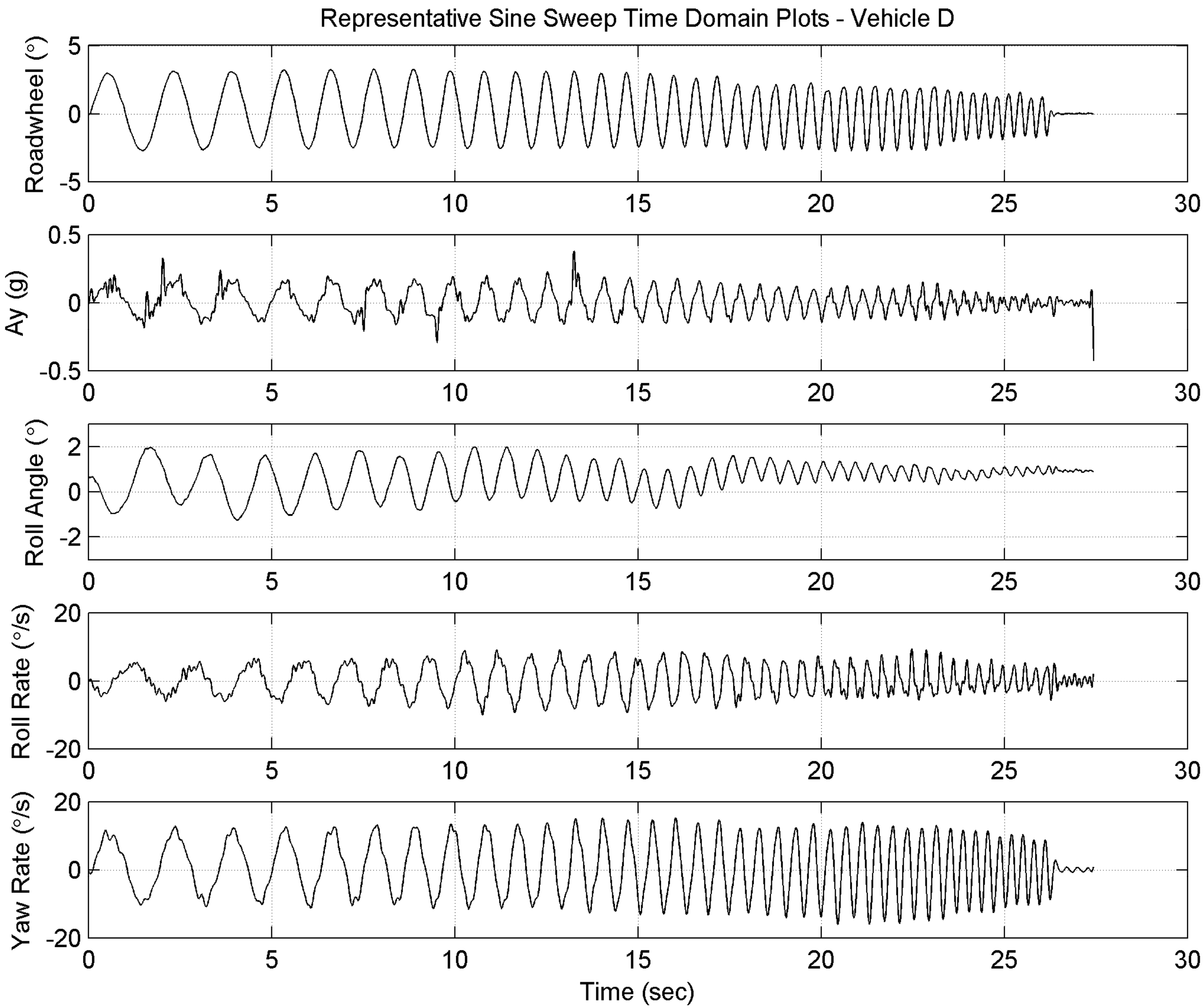

Vehicle D - 25 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

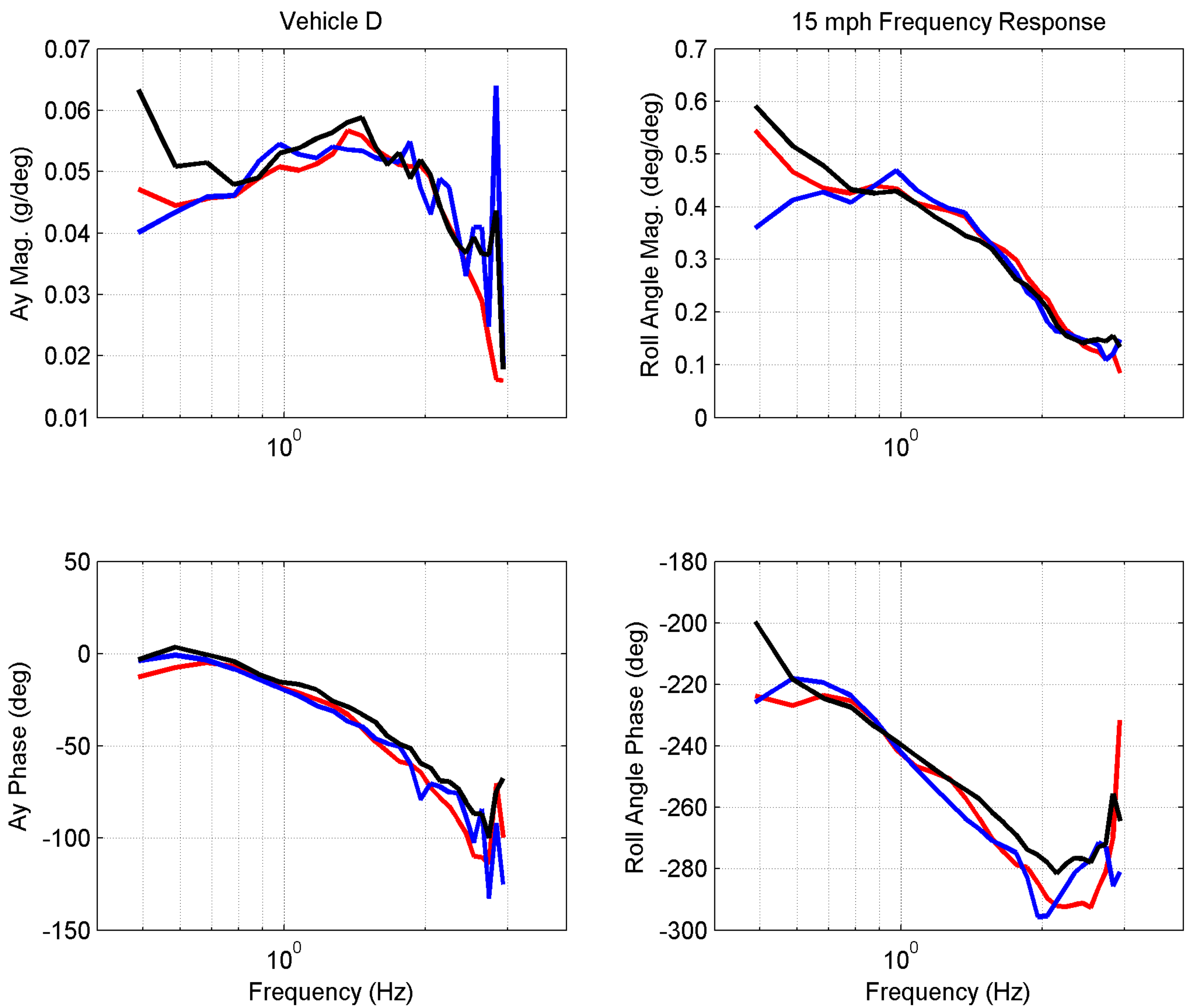

Vehicle D - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

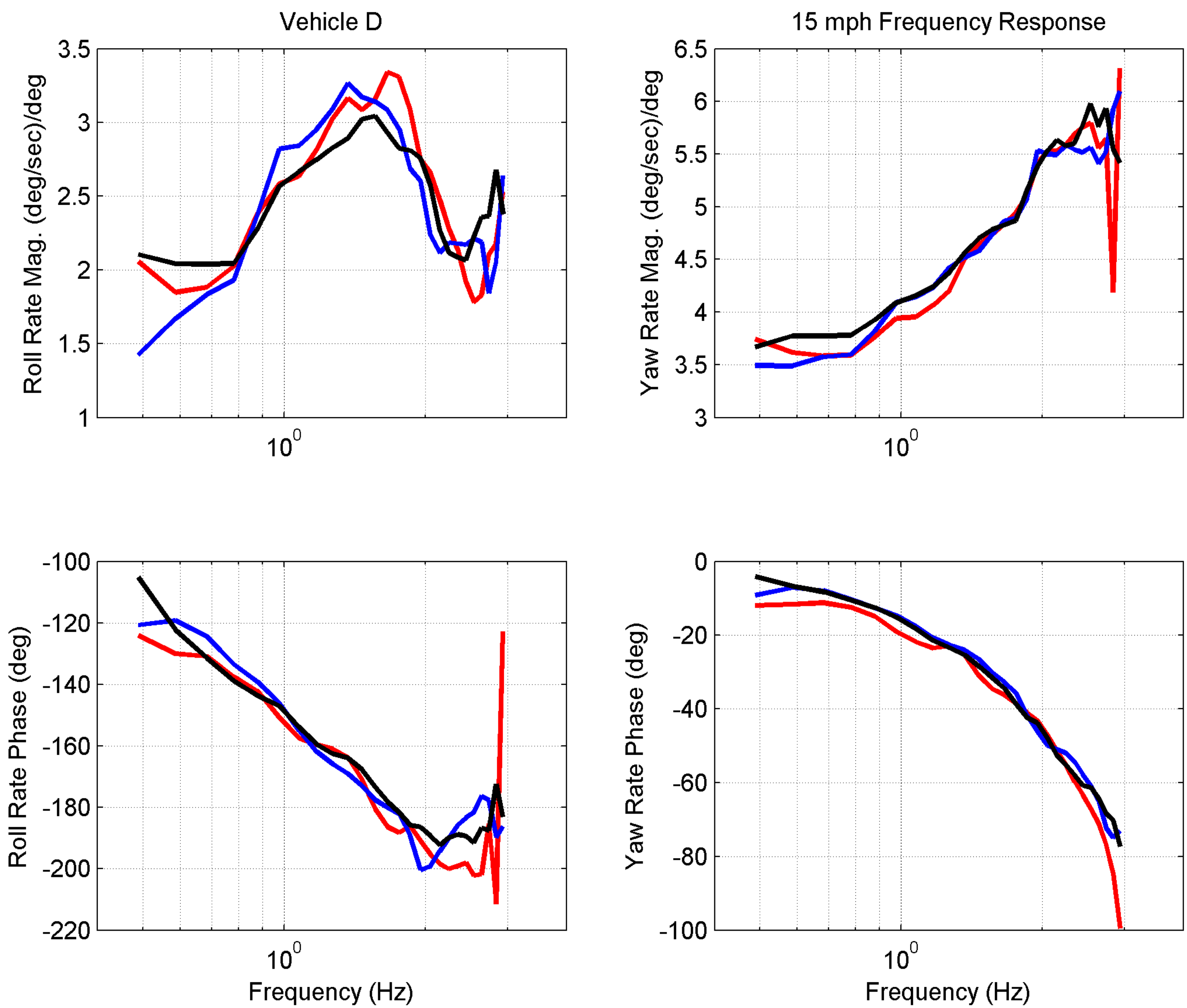


Vehicle D
Right Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

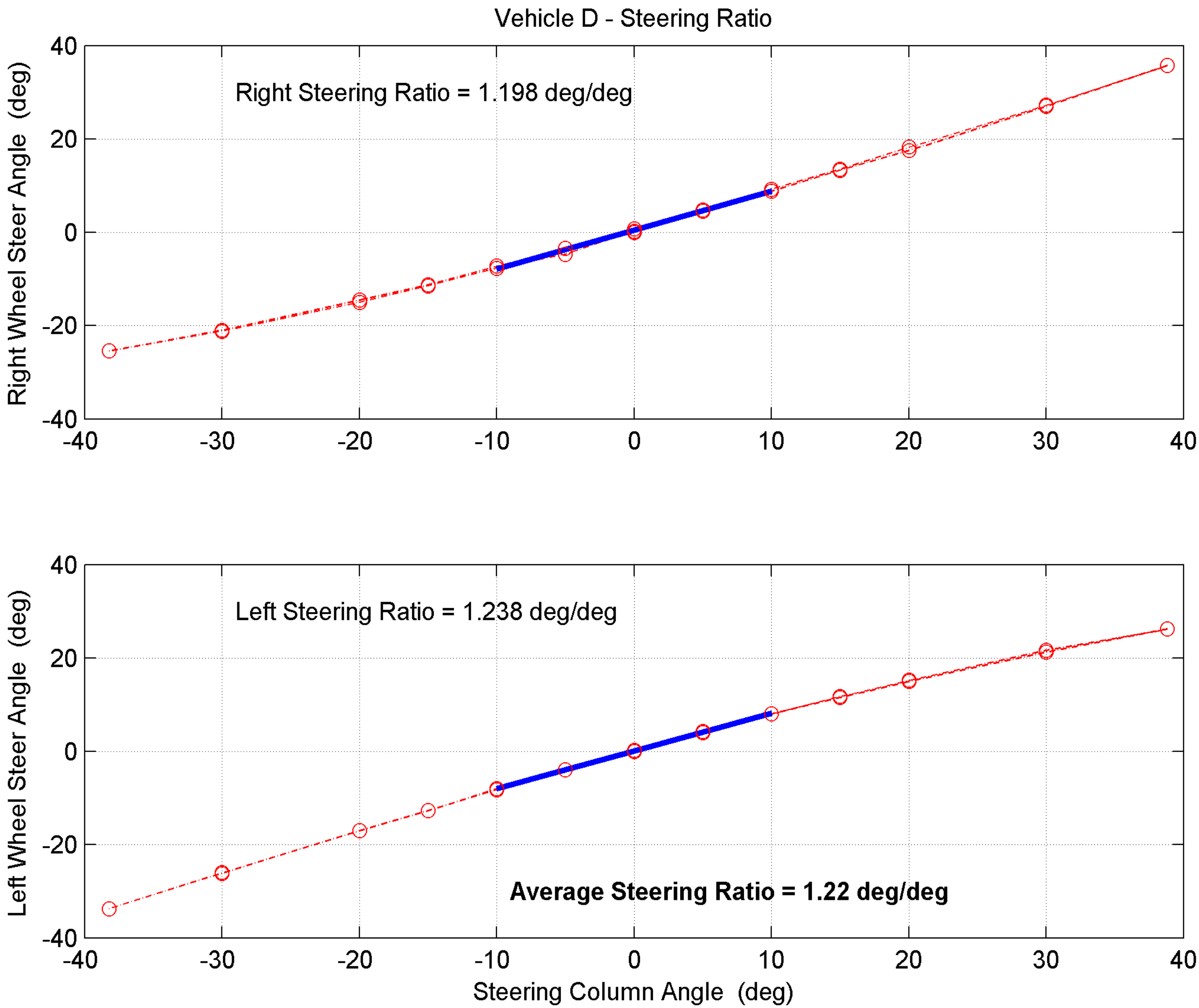

Vehicle D
Left Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)


Representative Sine Sweep Time Domain Plots - Vehicle D
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

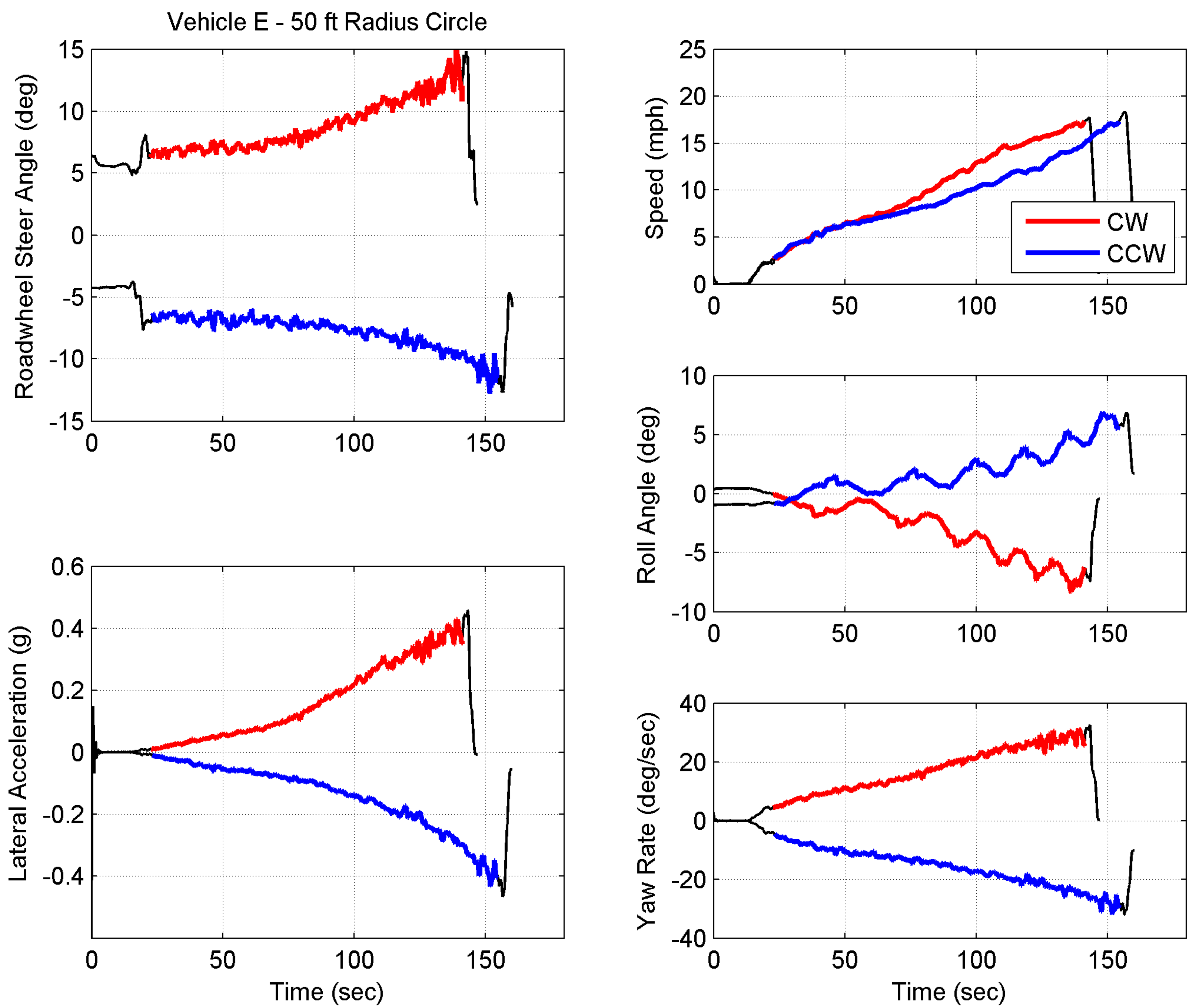

Vehicle D
15 mph Frequency Response
Ay Mag. (g/deg)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
10^0
Roll Angle Mag. (deg/deg)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10^0
Ay Phase (deg)
50
0
-50
-100
-150
10^0
Frequency (Hz)
Roll Angle Phase (deg)
-180
-200
-220
-240
-260
-280
-300
10^0
Frequency (Hz)

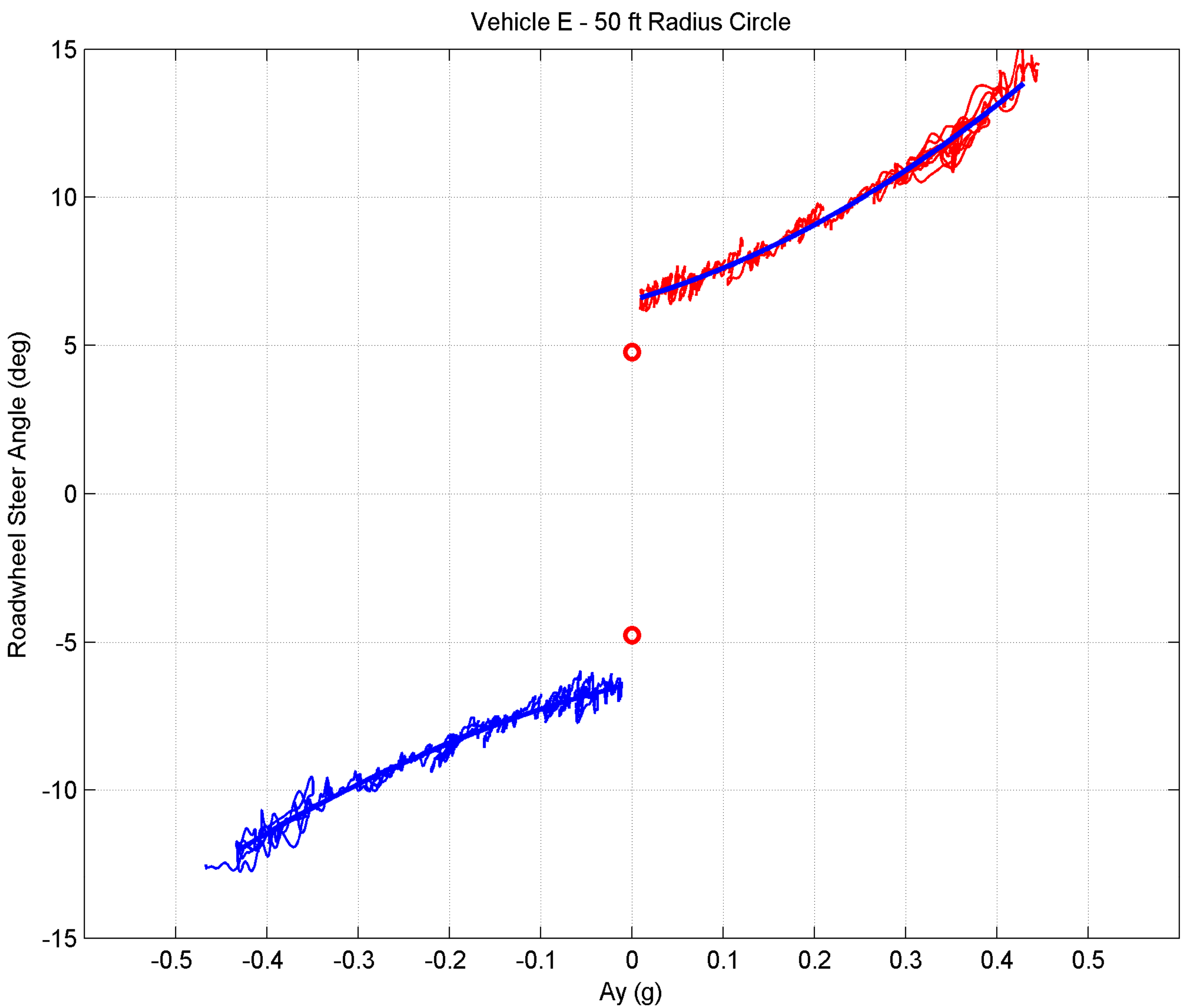


Vehicle D
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)

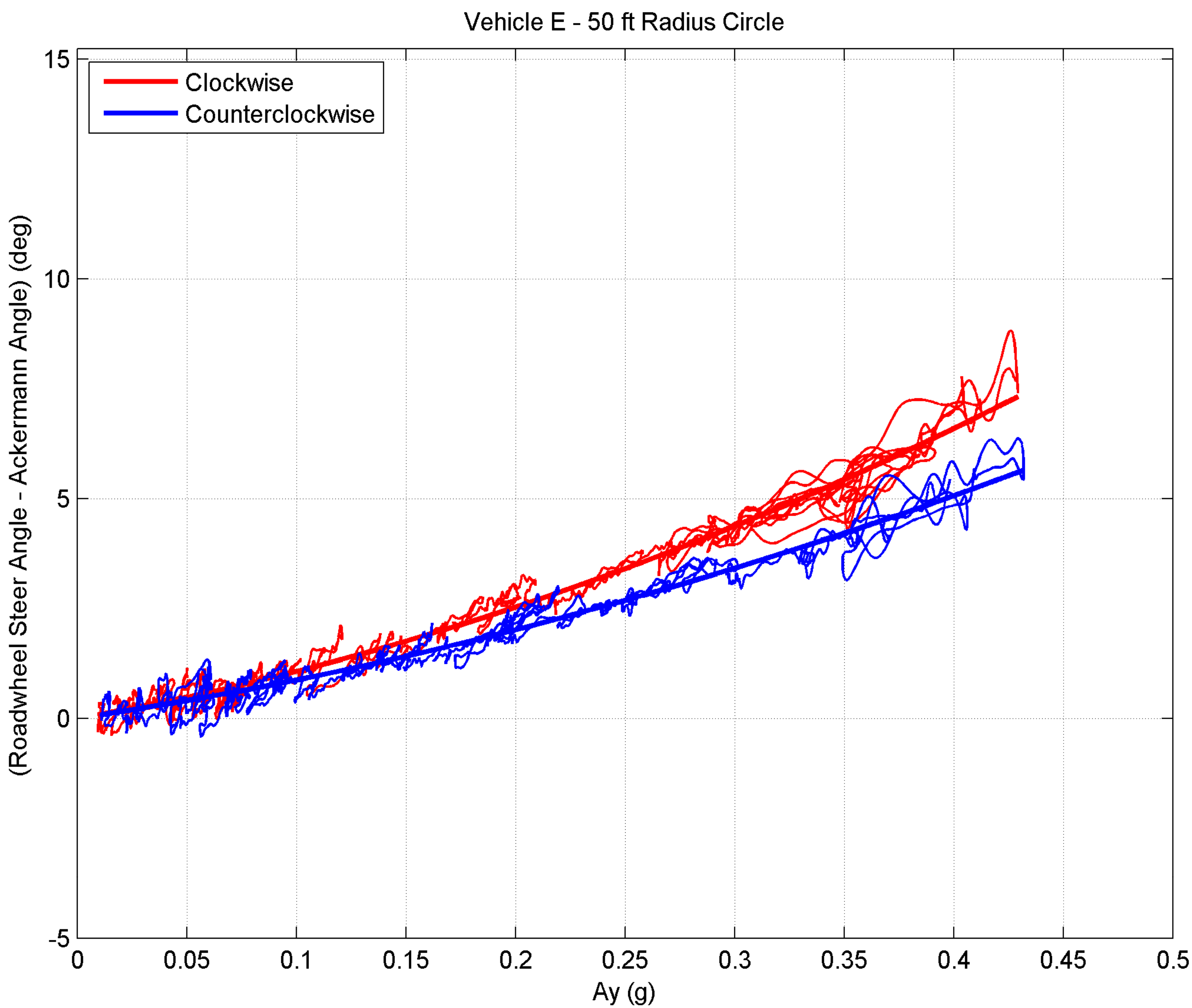


Vehicle D - Steering Ratio
Right Steering Ratio = 1.198 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-40
-30
-20
-10
0
10
20
30
40
Left Steering Ratio = 1.238 deg/deg
Average Steering Ratio = 1.22 deg/deg
Left Wheel Steer Angle (deg)
Steering Column Angle (deg)

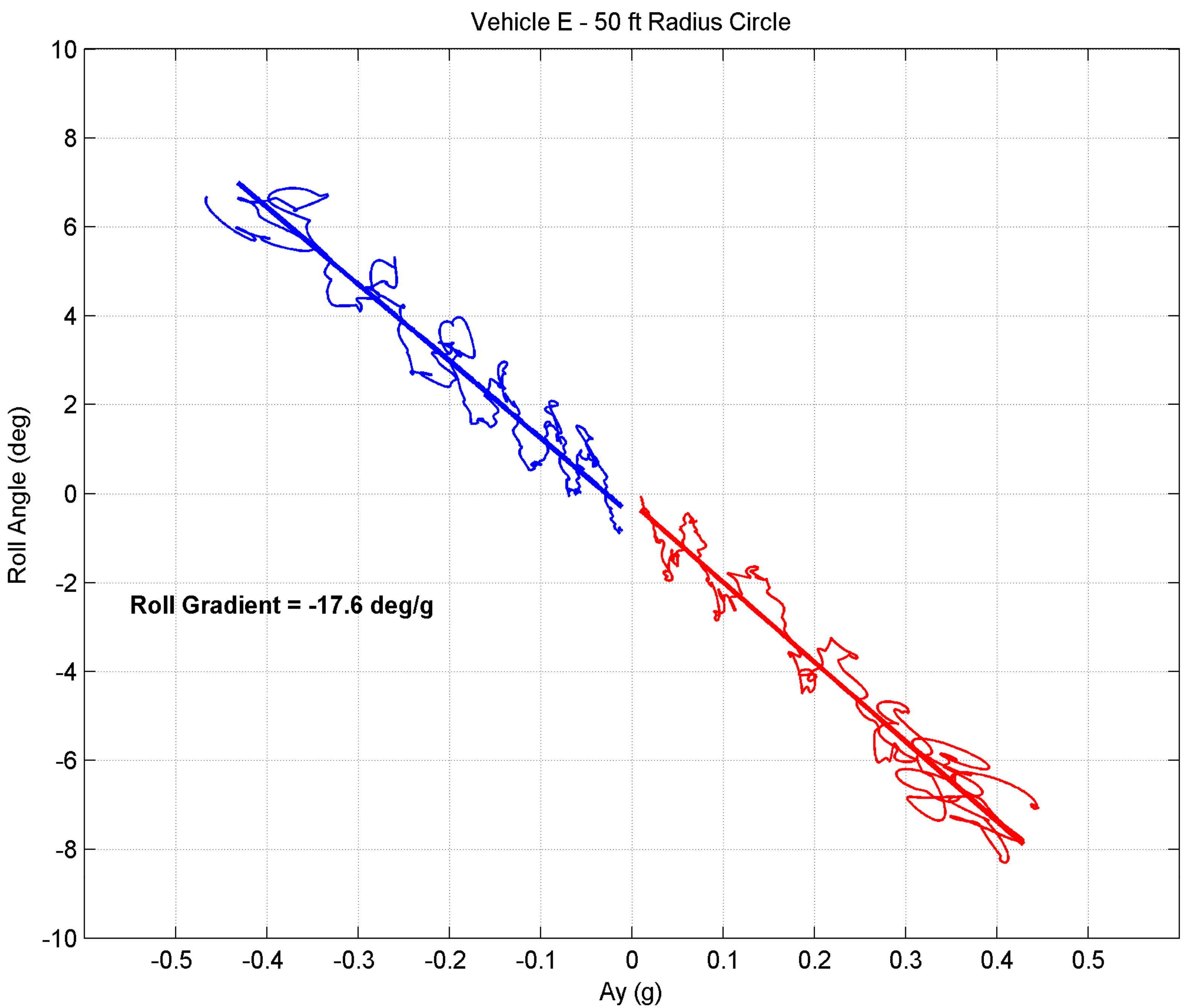

Vehicle E - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



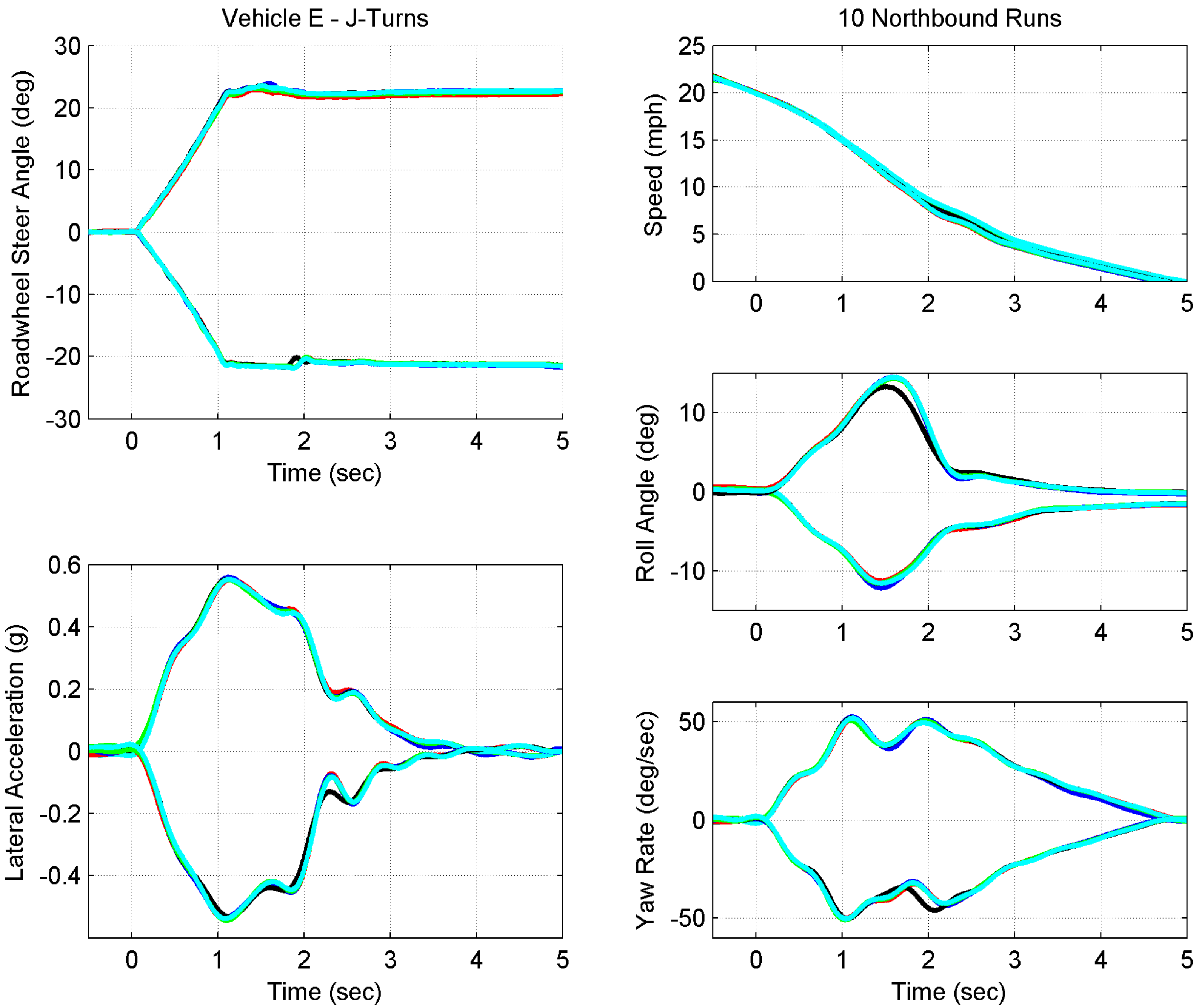
Vehicle E - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)



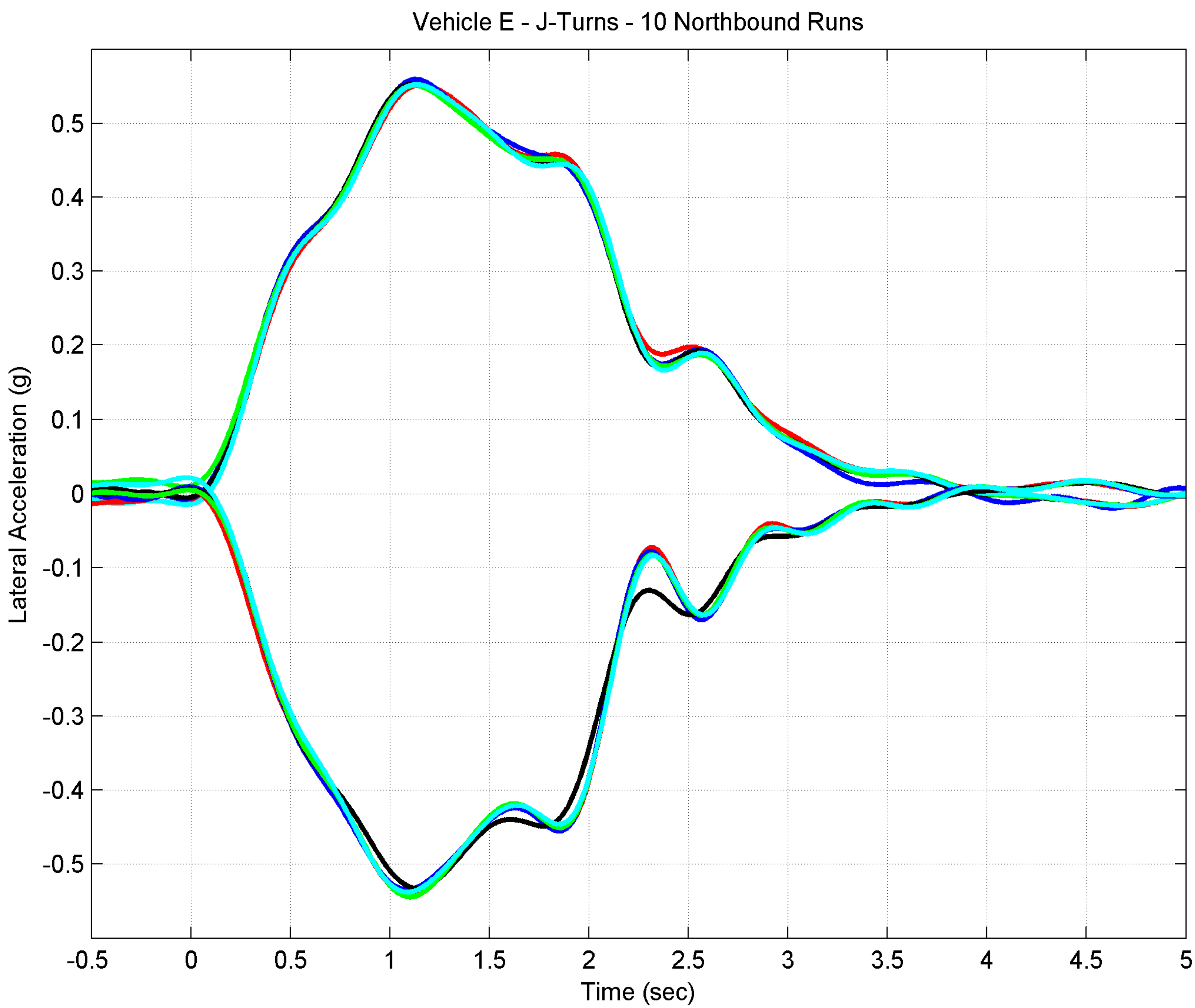
Vehicle E - 50 ft Radius Circle
Clockwise
Counterclockwise
(Roadwheel Steer Angle - Ackermann Angle) (deg)
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Ay (g)

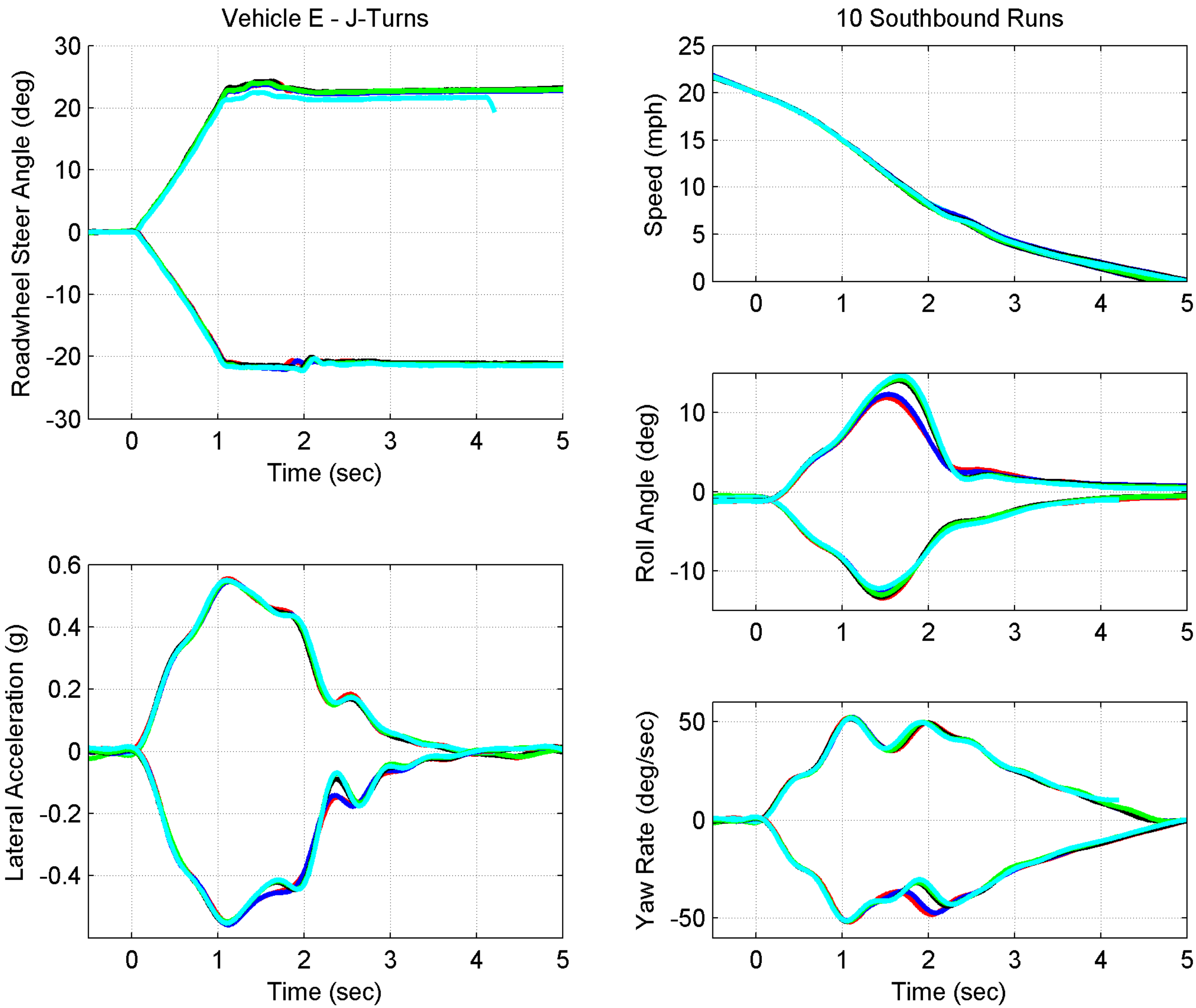


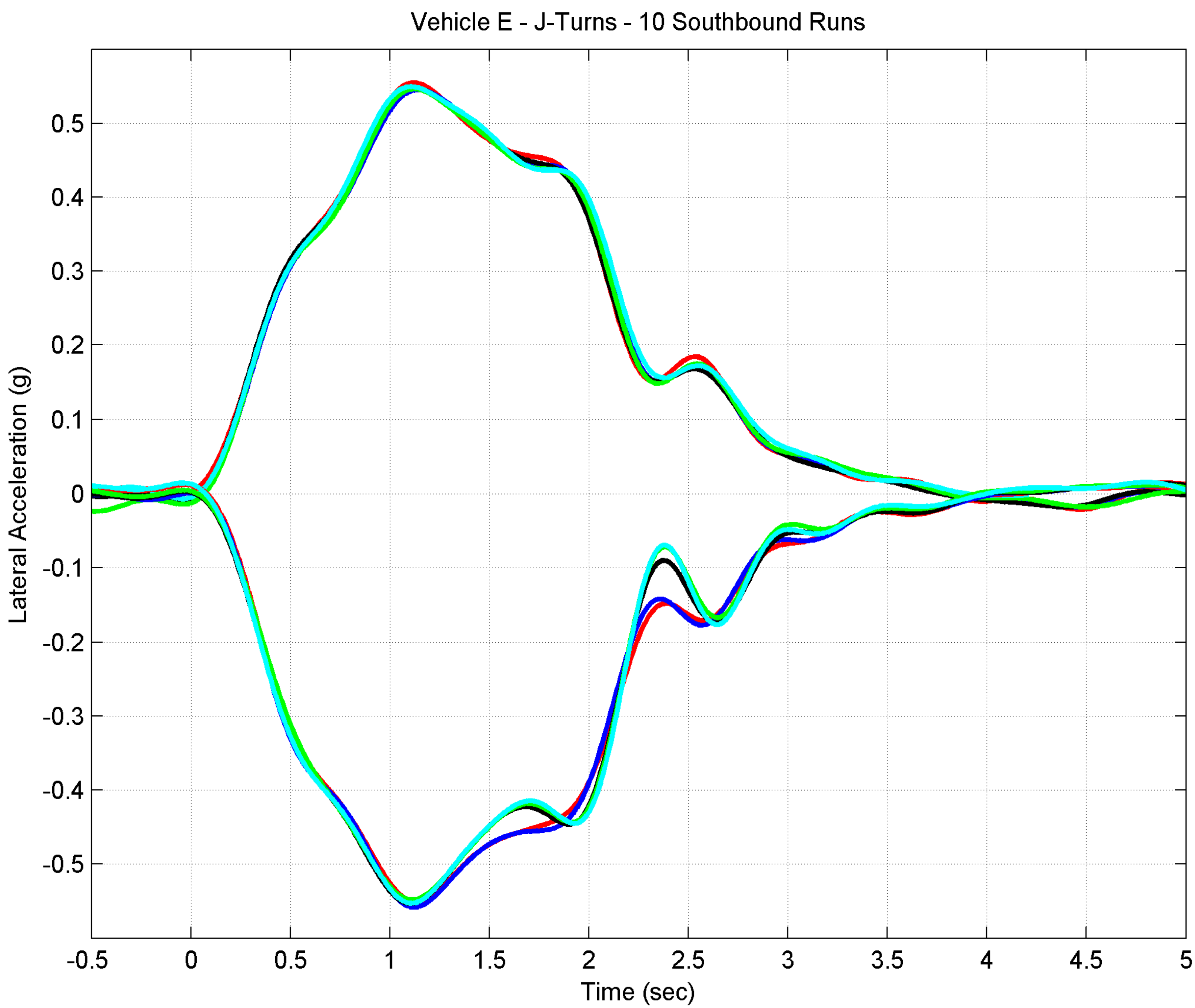
Vehicle E - 50 ft Radius Circle
Roll Gradient = -17.6 deg/g
Roll Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5



Vehicle E - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle E - J-Turns - 10 Northbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle E - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



Vehicle E - J-Turns - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle E

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.5518	-0.5406
2	0.5592	-0.5350
3	0.5528	-0.5333
4	0.5511	-0.5449
5	0.5525	-0.5383
Mean Value of 5 Runs	0.5535	-0.5384
Standard Deviation of 5 Runs	0.003	0.005

Average of 10 Northbound Runs

0.5459

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.5547	-0.5518
2	0.5452	-0.5587
3	0.5474	-0.5537
4	0.5465	-0.5484
5	0.5494	-0.5532
Mean Value of 5 Runs	0.5486	-0.5532
Standard Deviation of 5 Runs	0.004	0.004

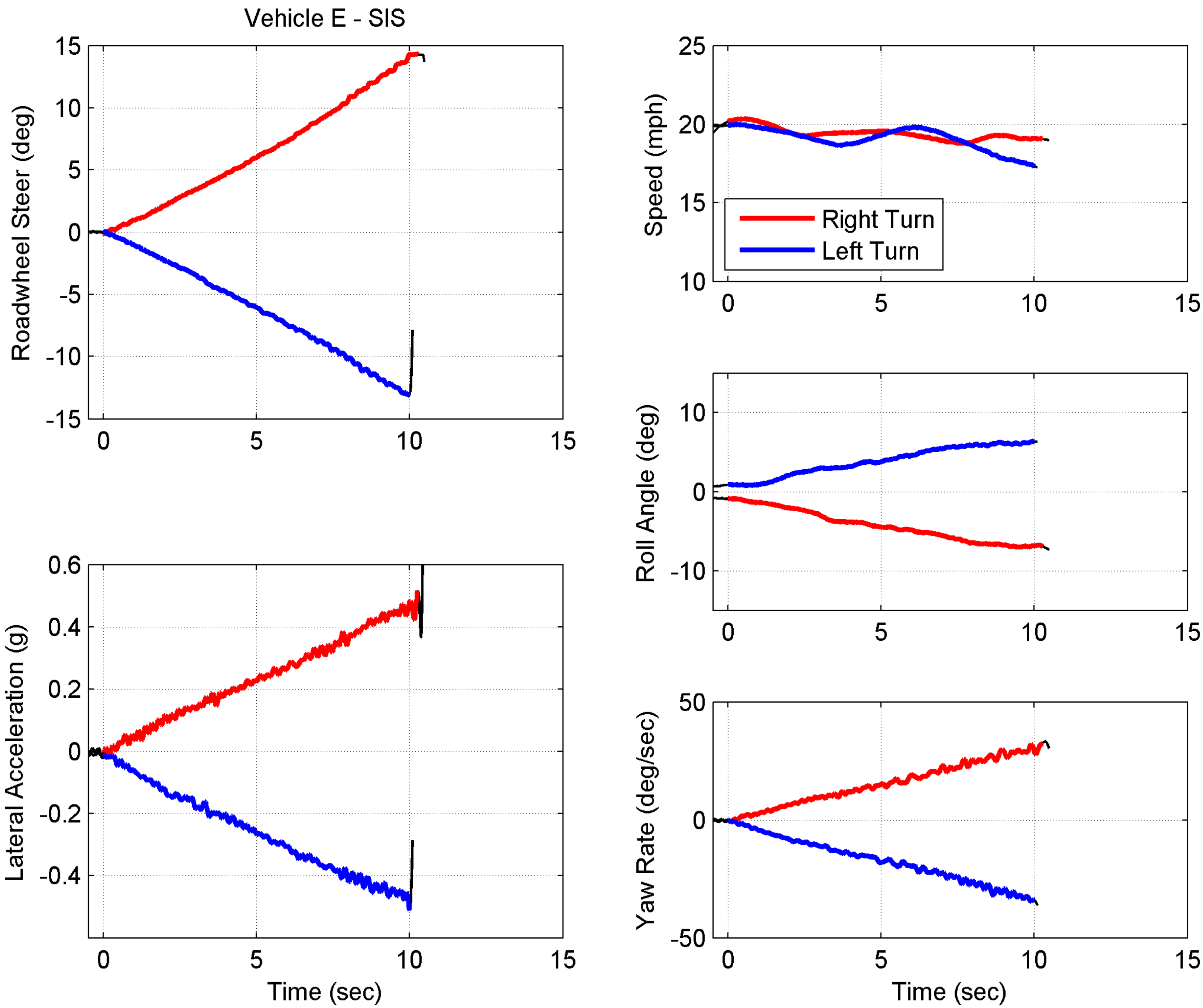
Average of 10 Southbound Runs

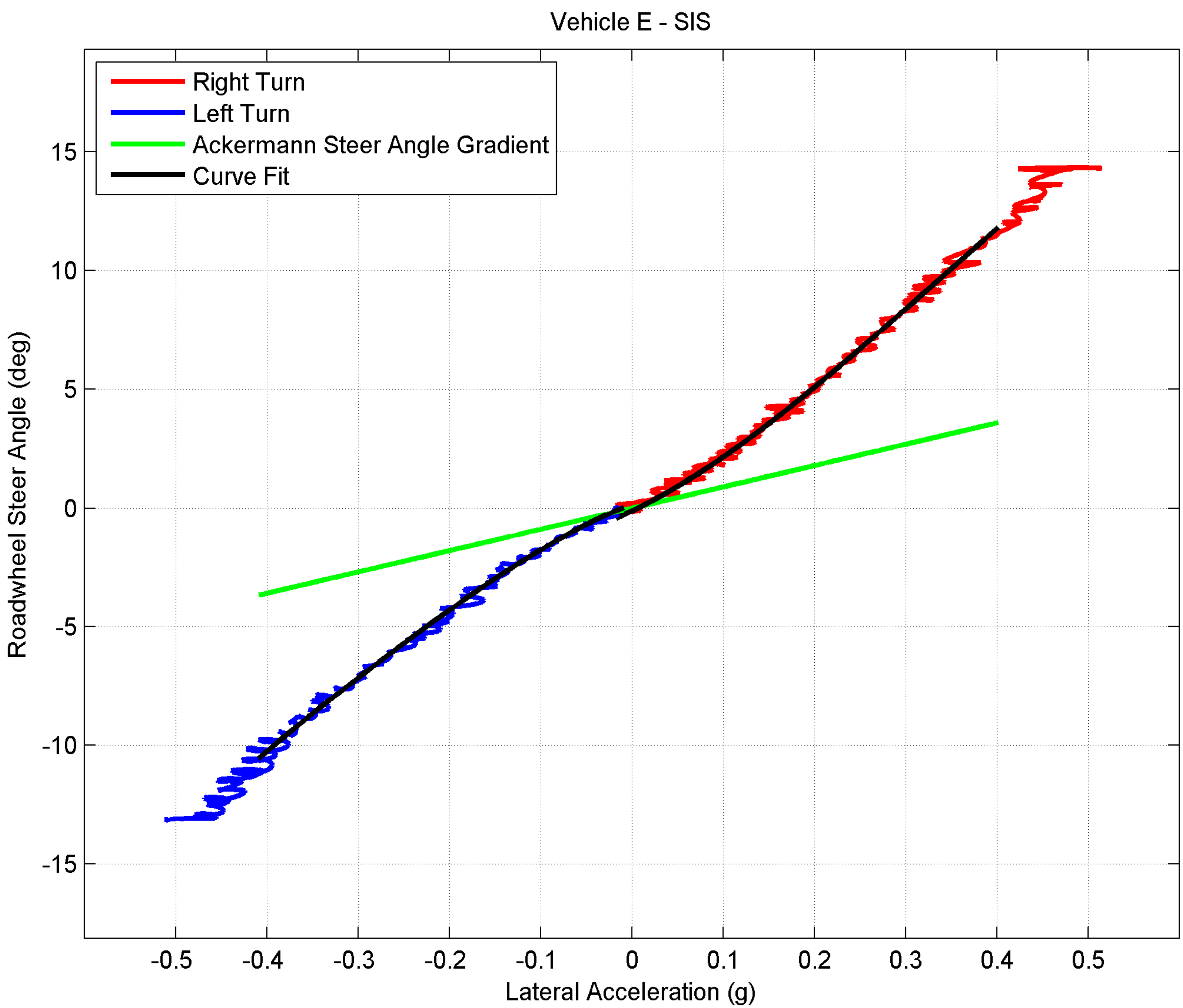
0.5509

Average of All 20 Runs

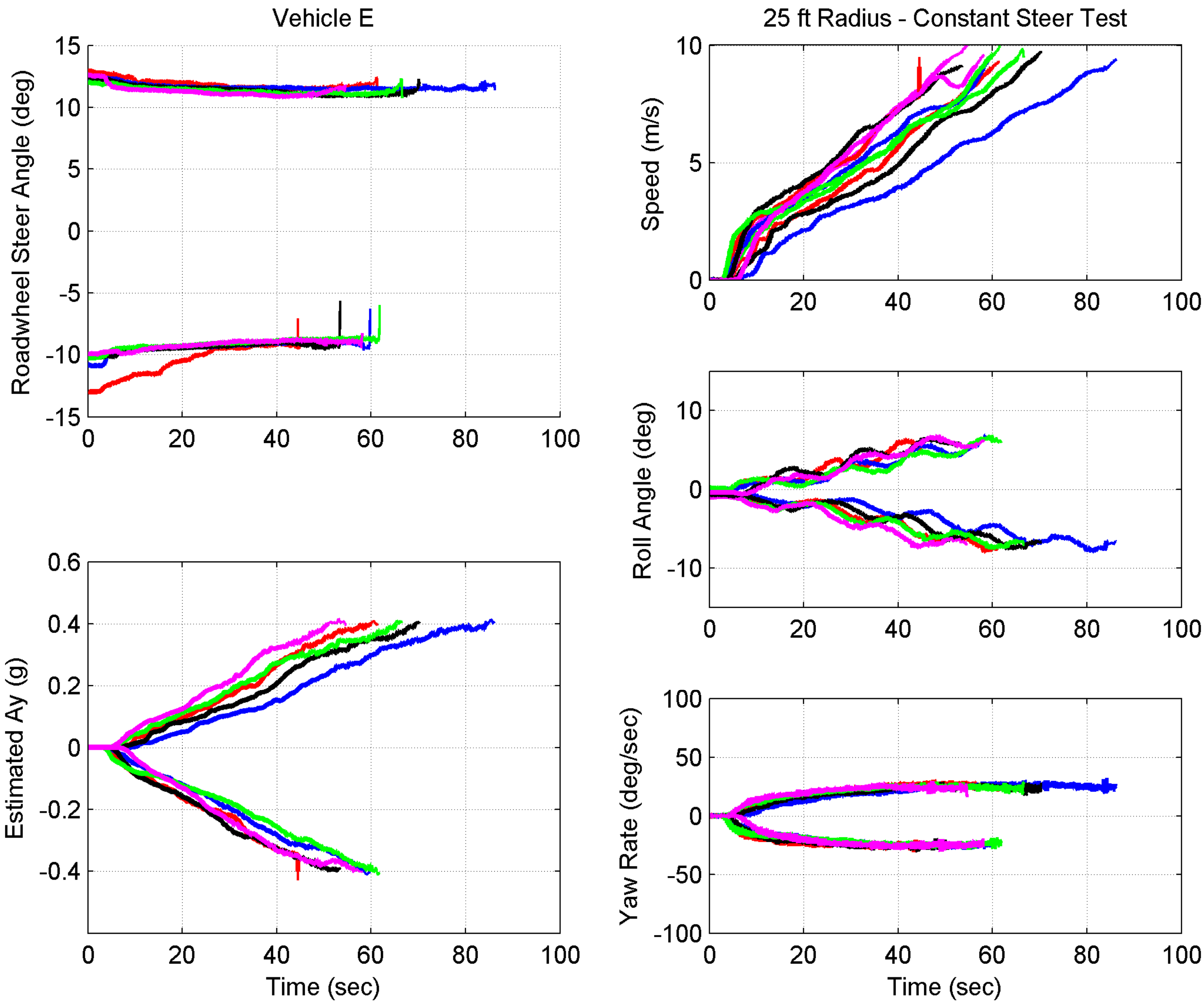
0.548

Threshold Ay

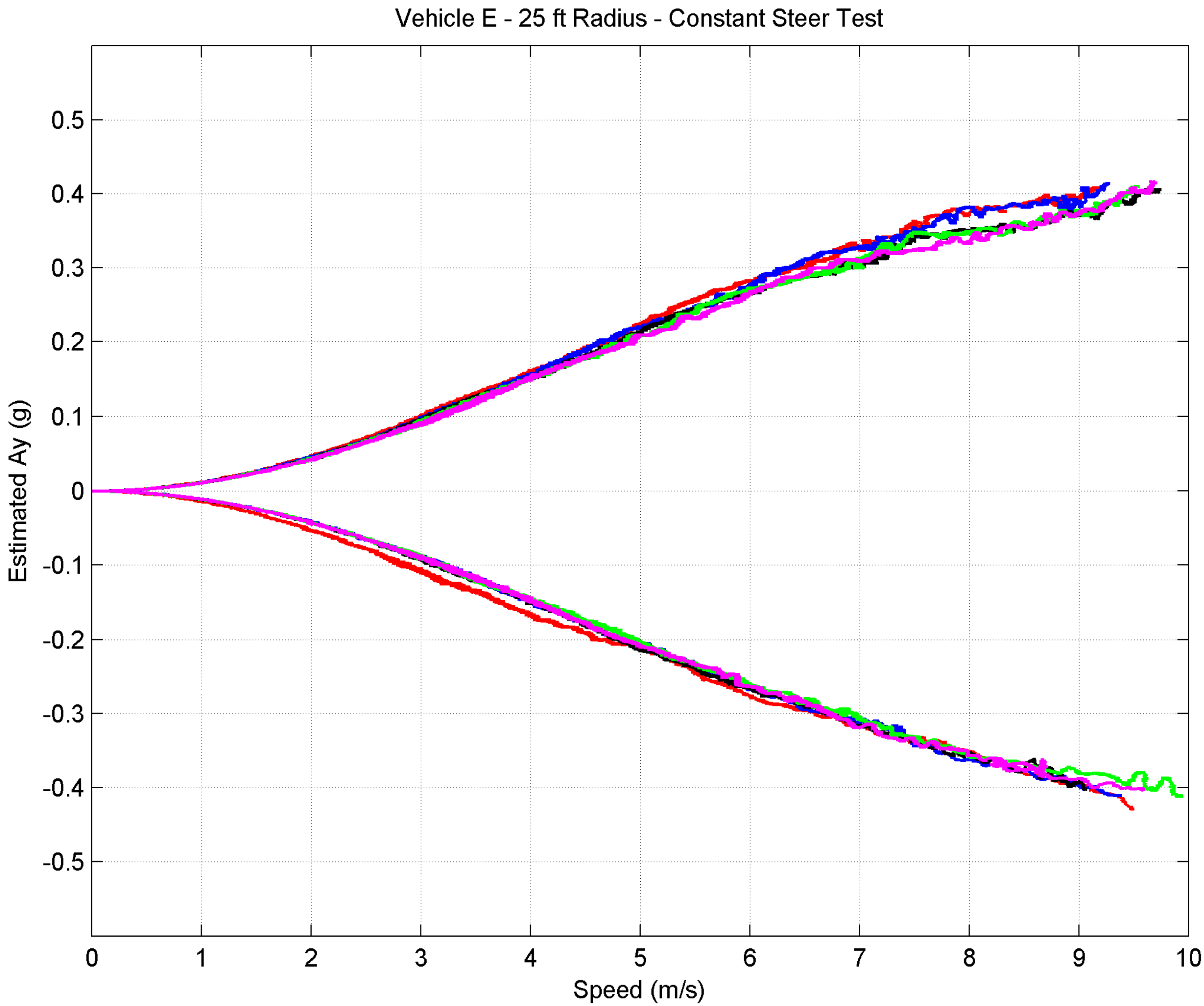

Vehicle E - SIS
Roadwheel Steer (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)



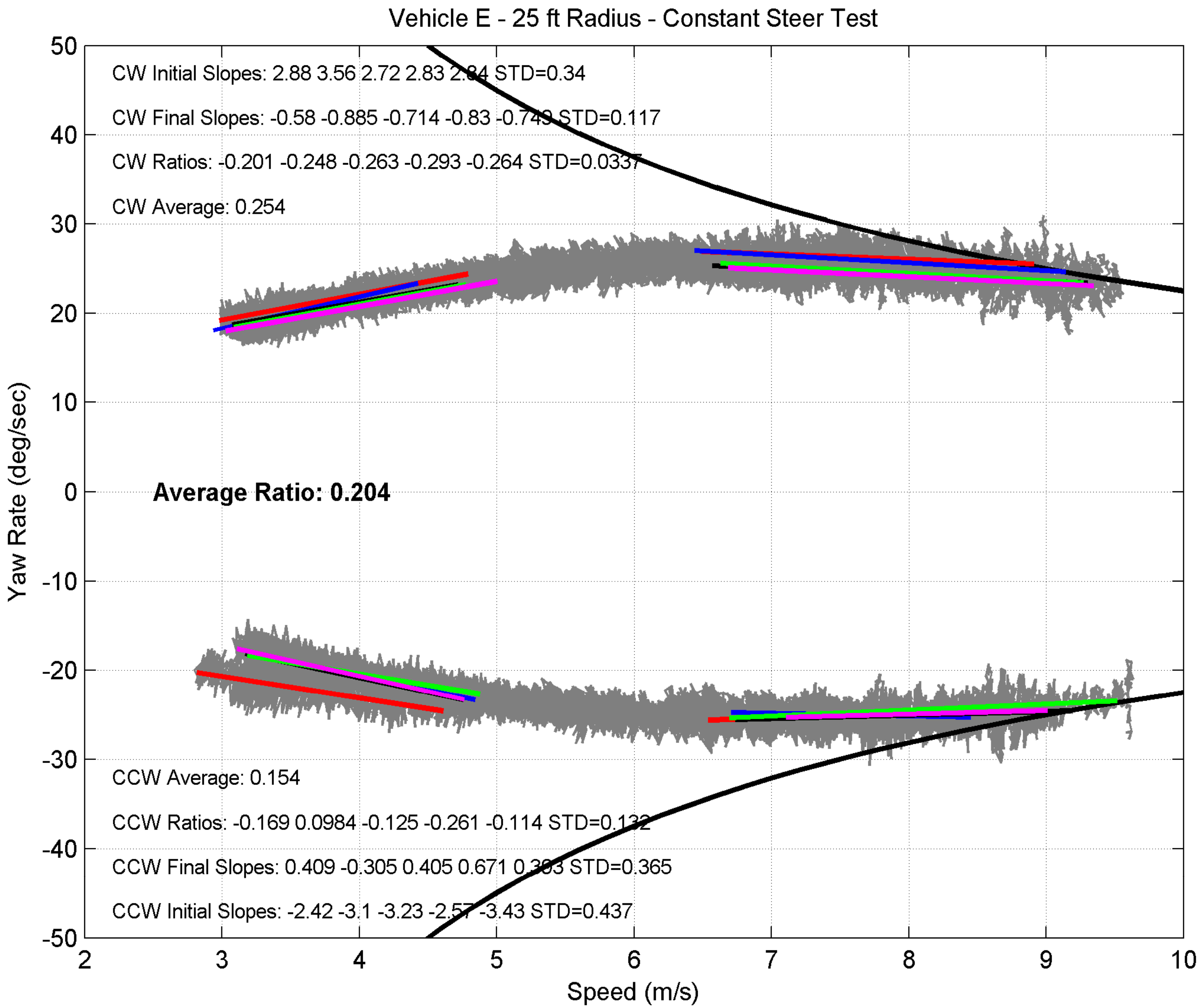
Vehicle E - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)



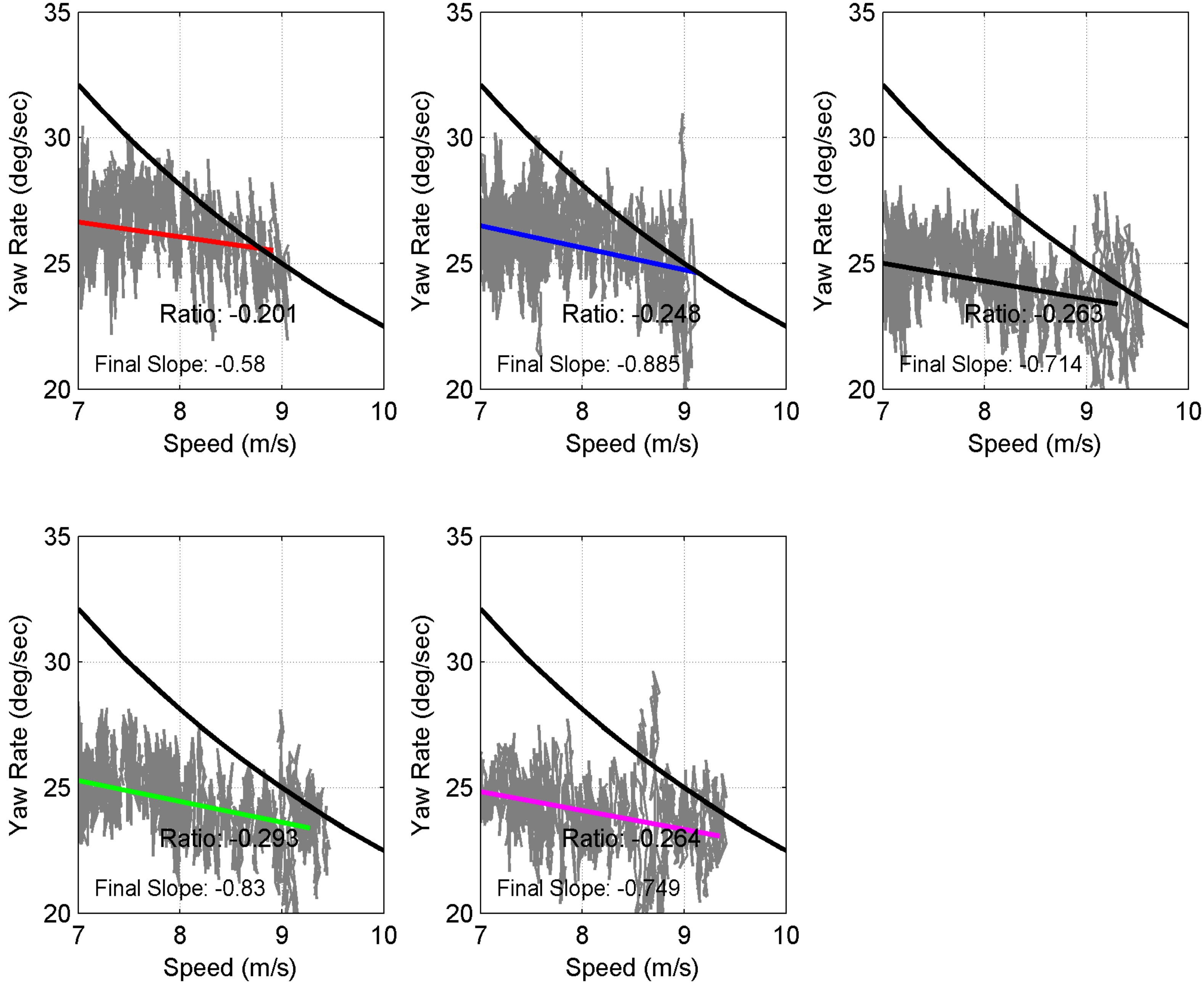
Vehicle E
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

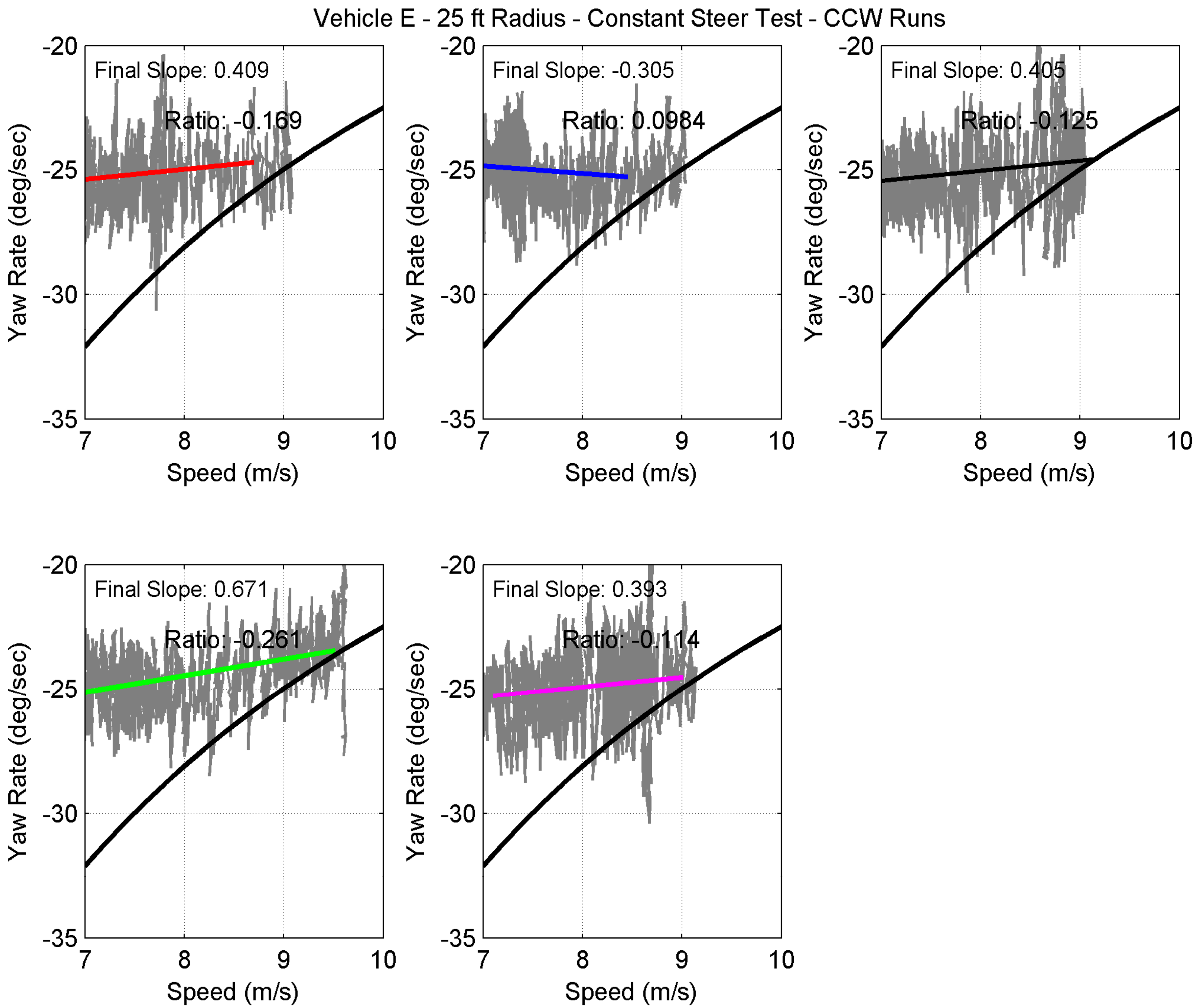


Vehicle E - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10

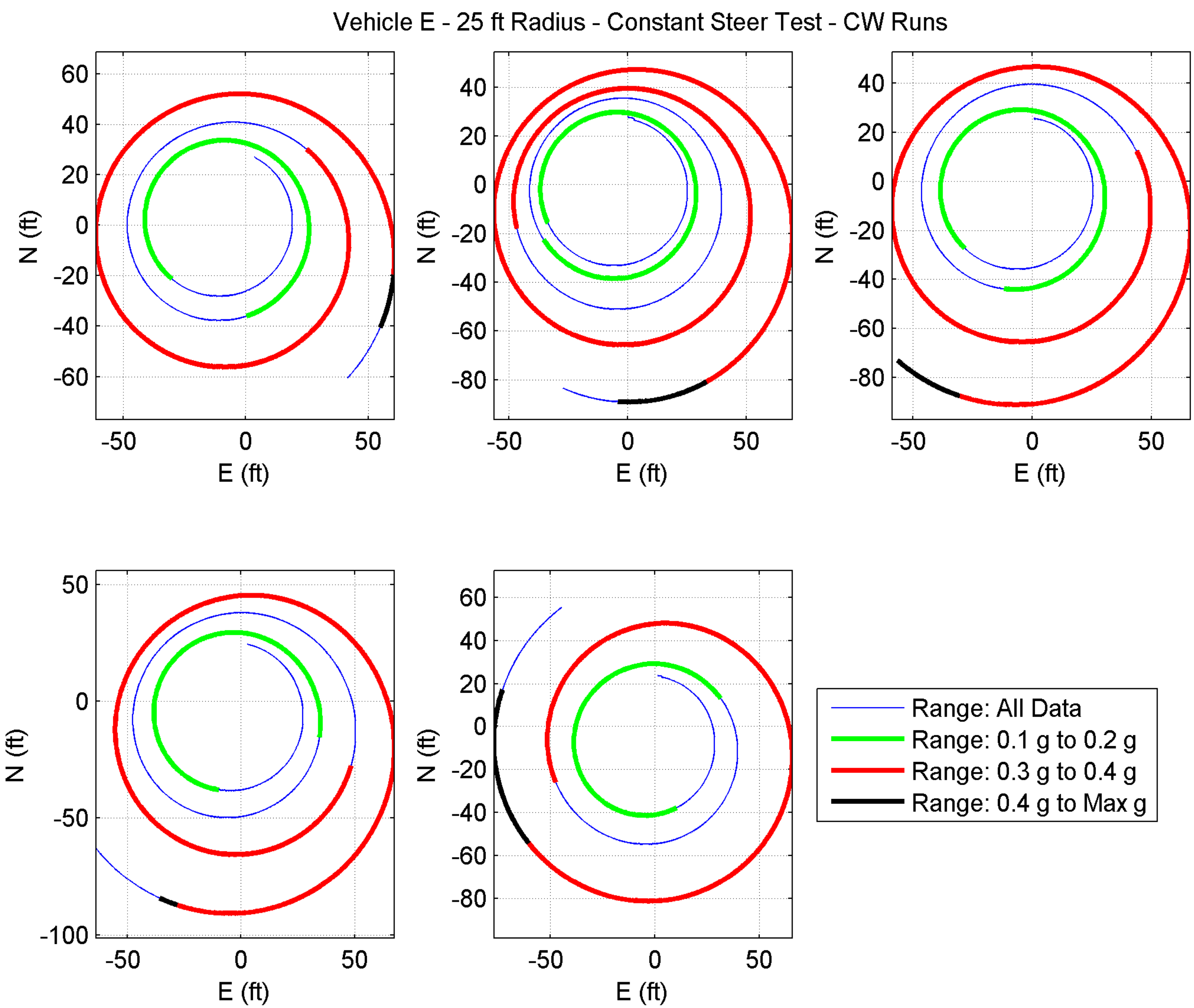

Vehicle E - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 2.88 3.56 2.72 2.83 2.84 STD=0.34
CW Final Slopes: -0.58 -0.885 -0.714 -0.83 -0.749 STD=0.117
CW Ratios: -0.201 -0.248 -0.263 -0.293 -0.264 STD=0.0337
CW Average: 0.254
Average Ratio: 0.204
CCW Average: 0.154
CCW Ratios: -0.169 0.0984 -0.125 -0.261 -0.114 STD=0.132
CCW Final Slopes: 0.409 -0.305 0.405 0.671 0.393 STD=0.365
CCW Initial Slopes: -2.42 -3.1 -3.23 -2.57 -3.43 STD=0.437
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8
9
10

Vehicle E - 25 ft Radius - Constant Steer Test - CW Runs

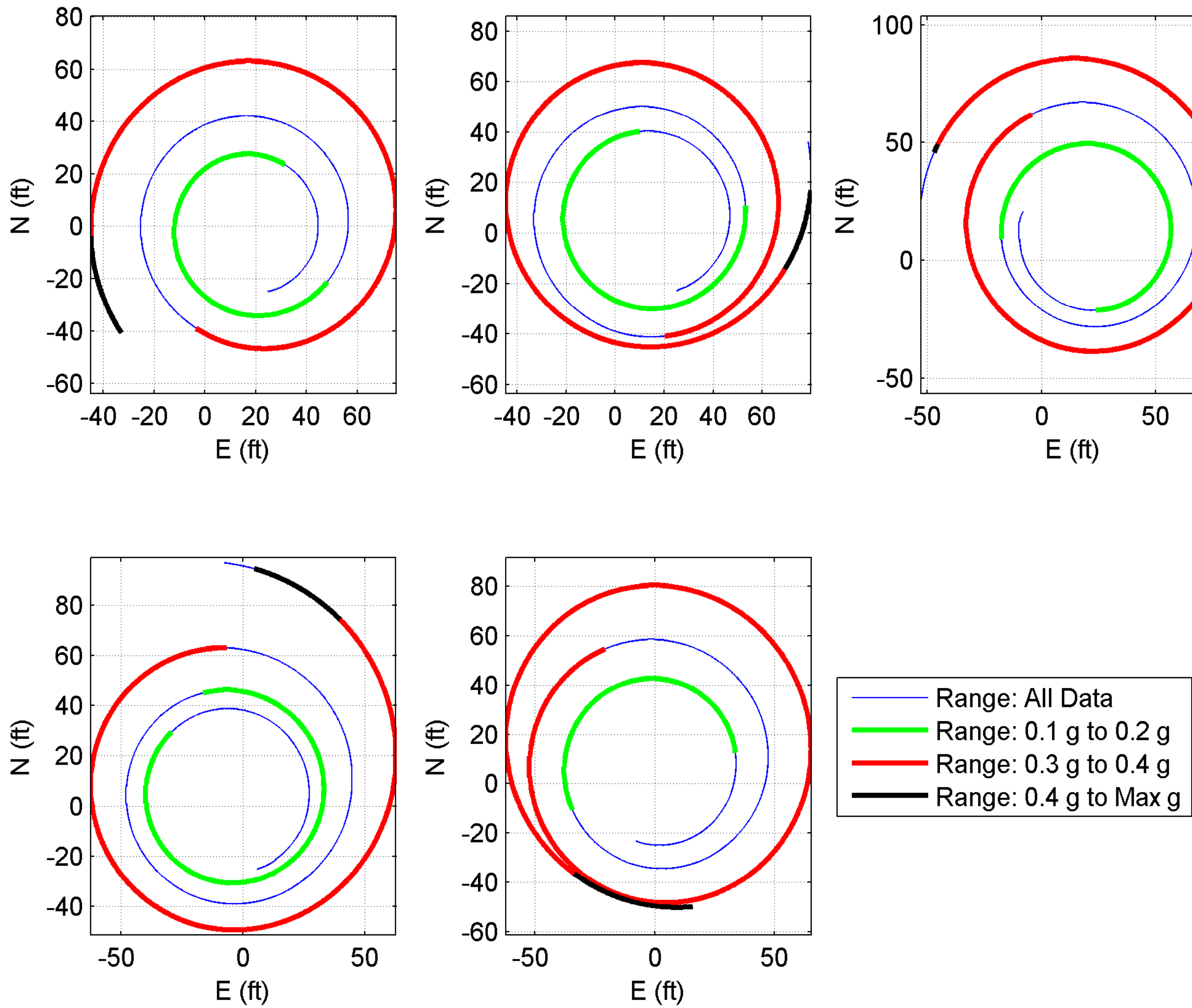


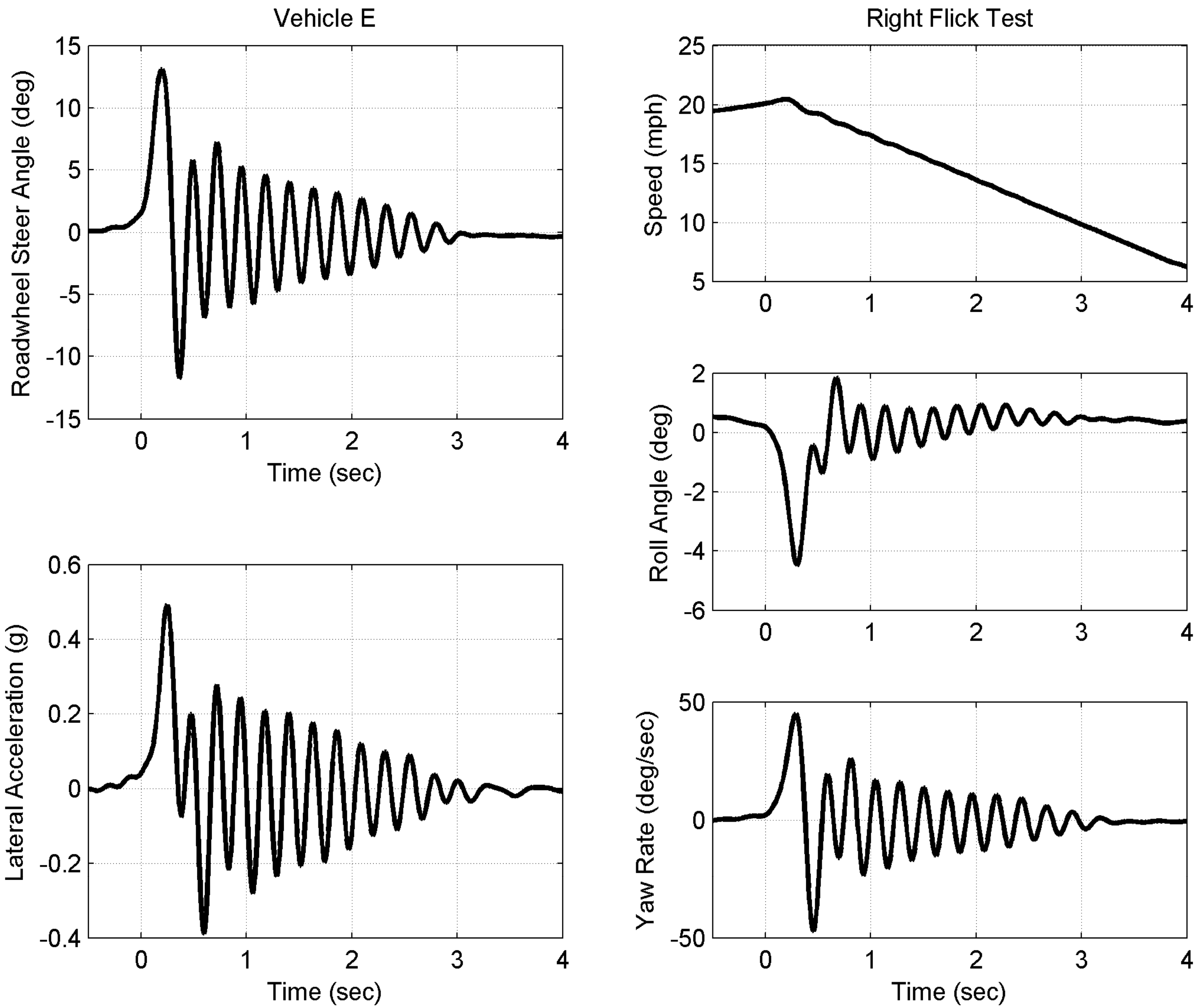


Vehicle E - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 0.409
Ratio: -0.169
Final Slope: -0.305
Ratio: 0.0984
Final Slope: 0.405
Ratio: -0.125
Final Slope: 0.671
Ratio: -0.261
Final Slope: 0.393
Ratio: -0.114
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
7
8
9
10

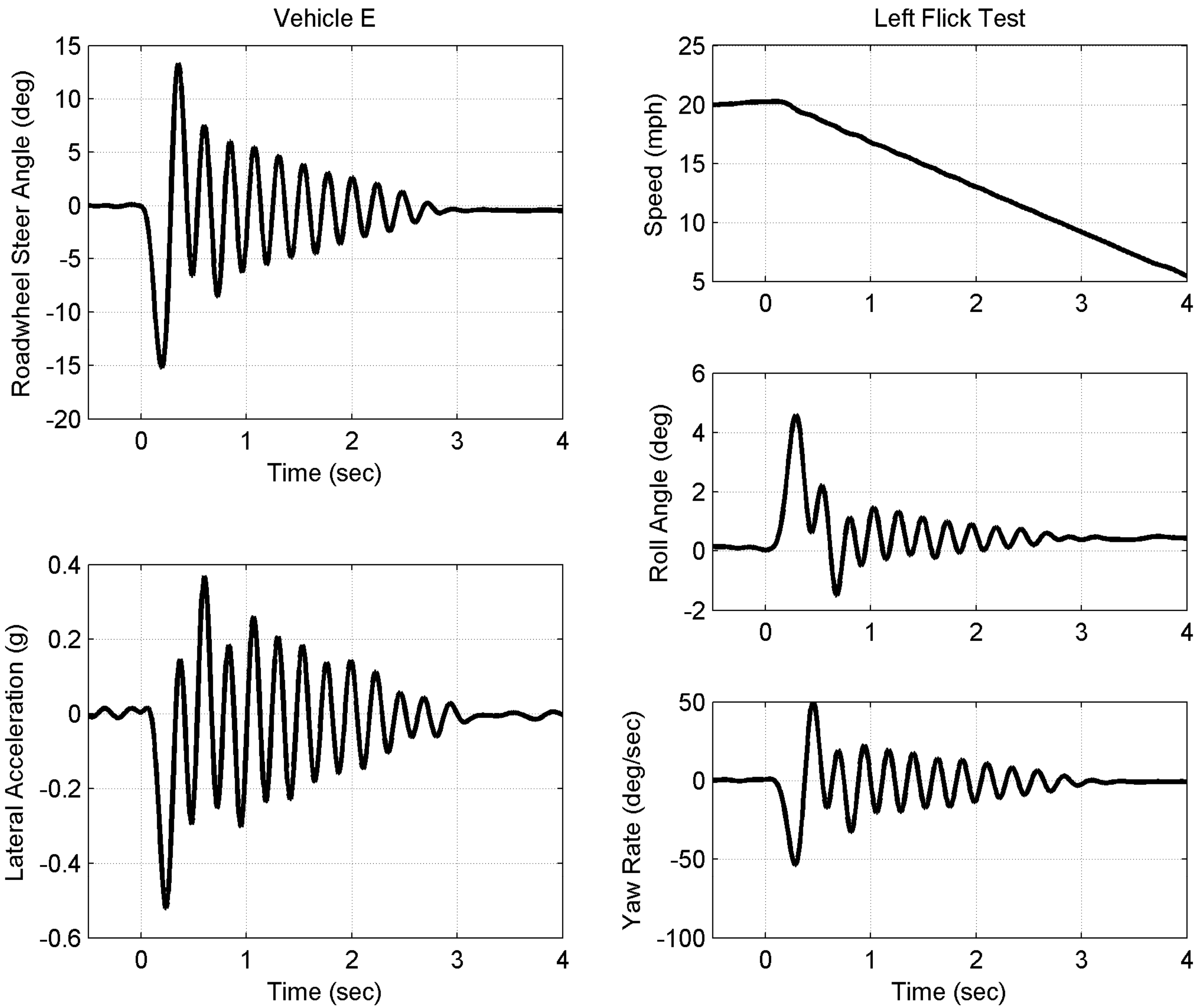

Vehicle E - 25 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

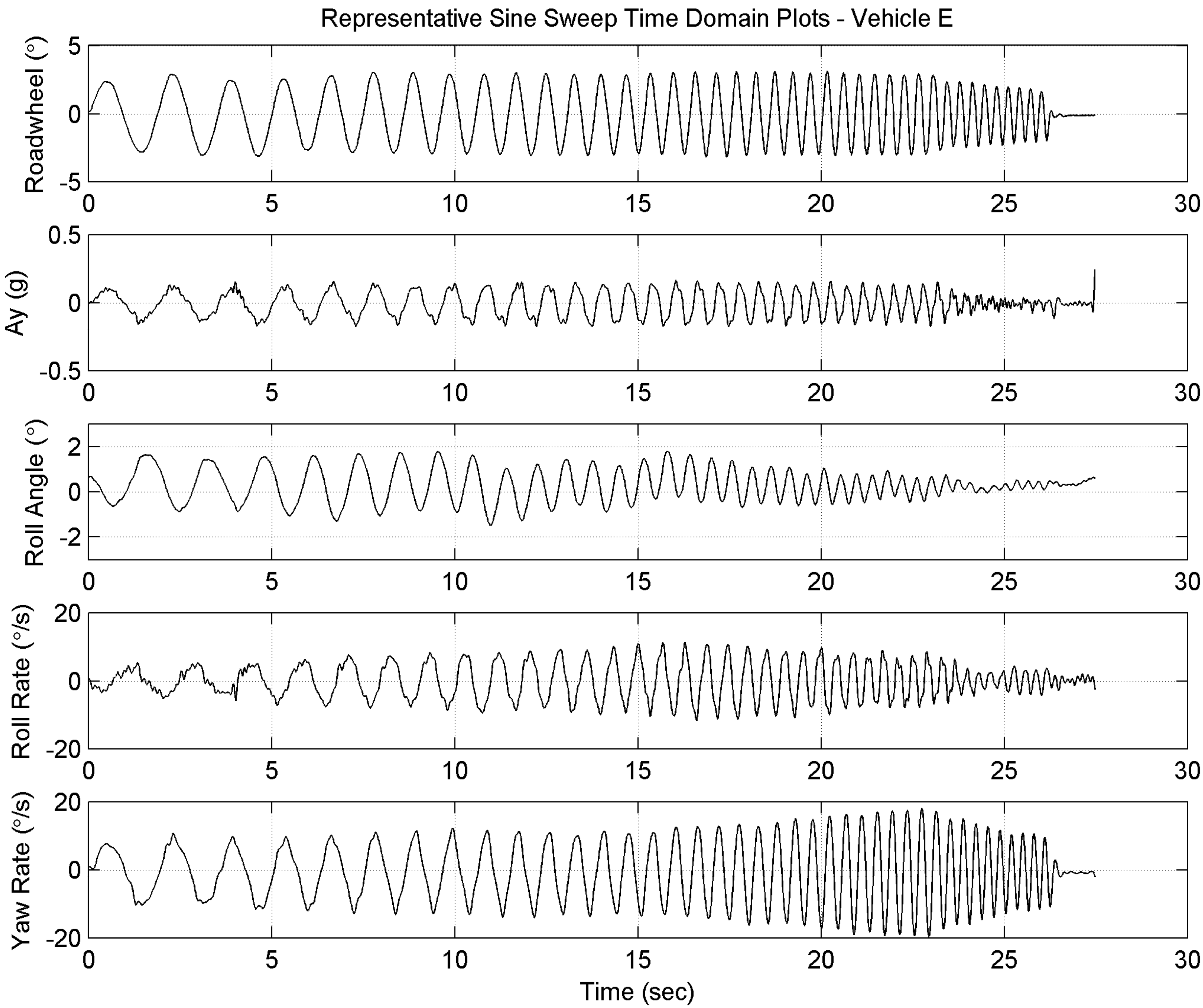
Vehicle E - 25 ft Radius - Constant Steer Test - CCW Runs



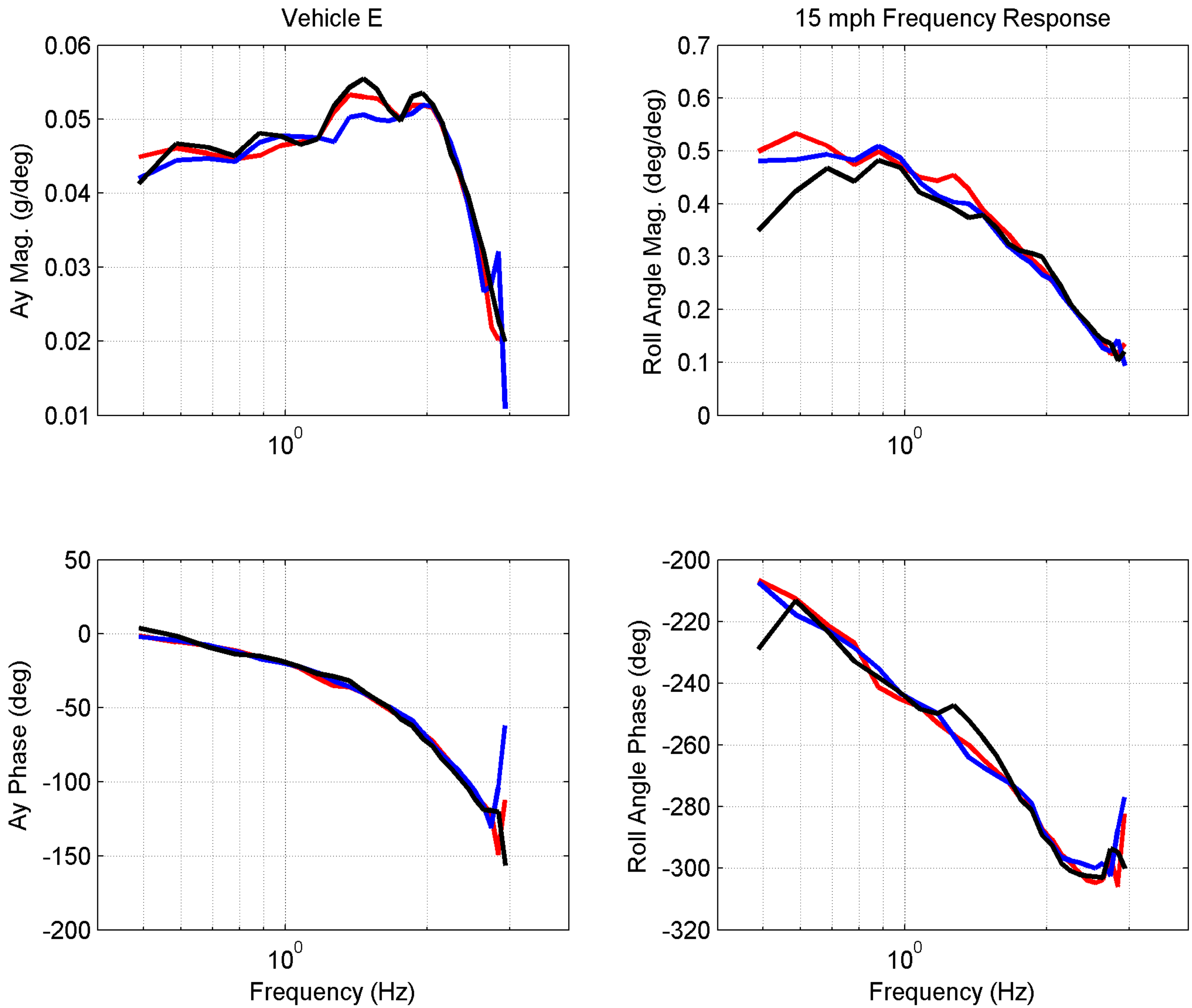


Vehicle E
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

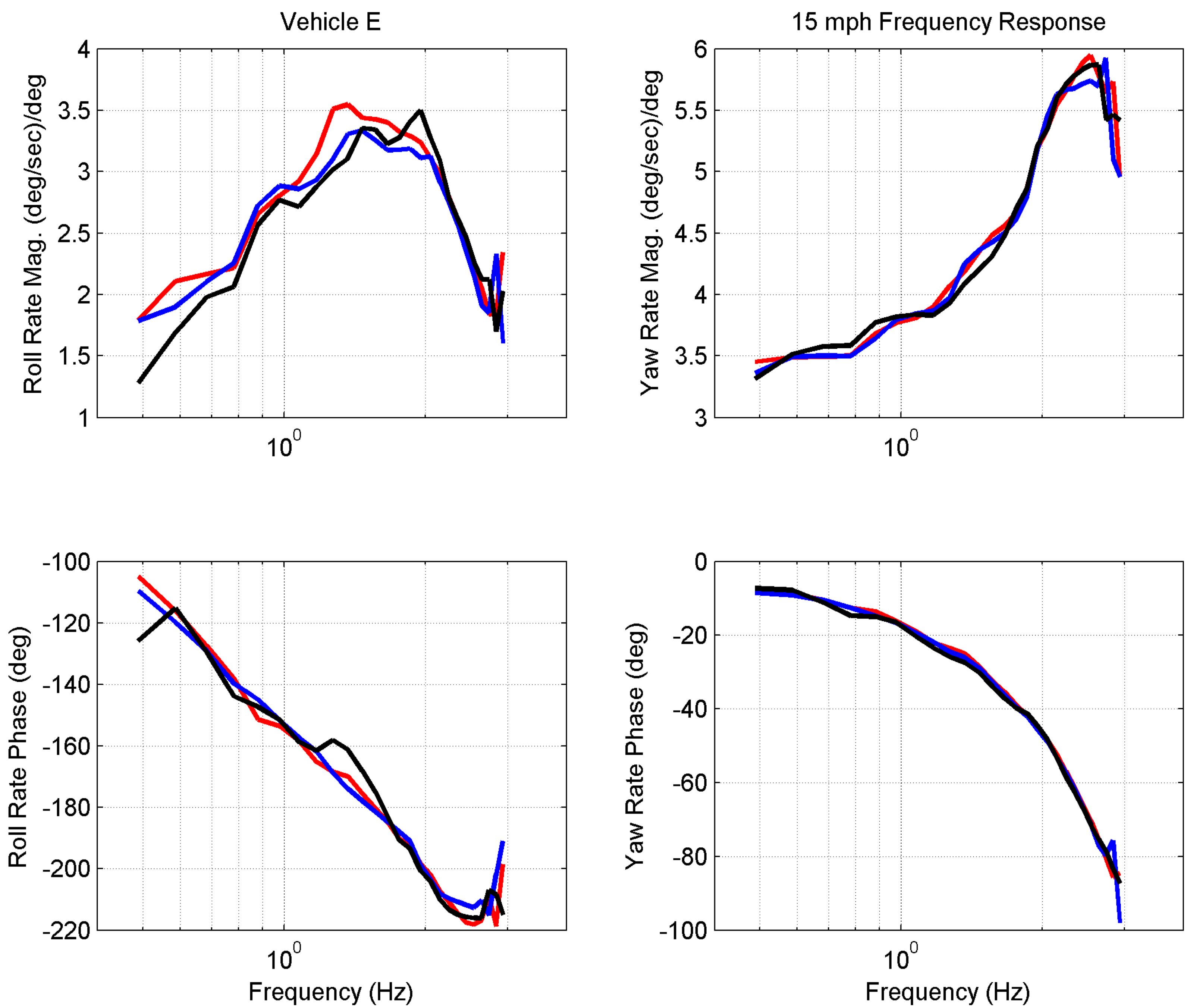

Vehicle E
Left Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



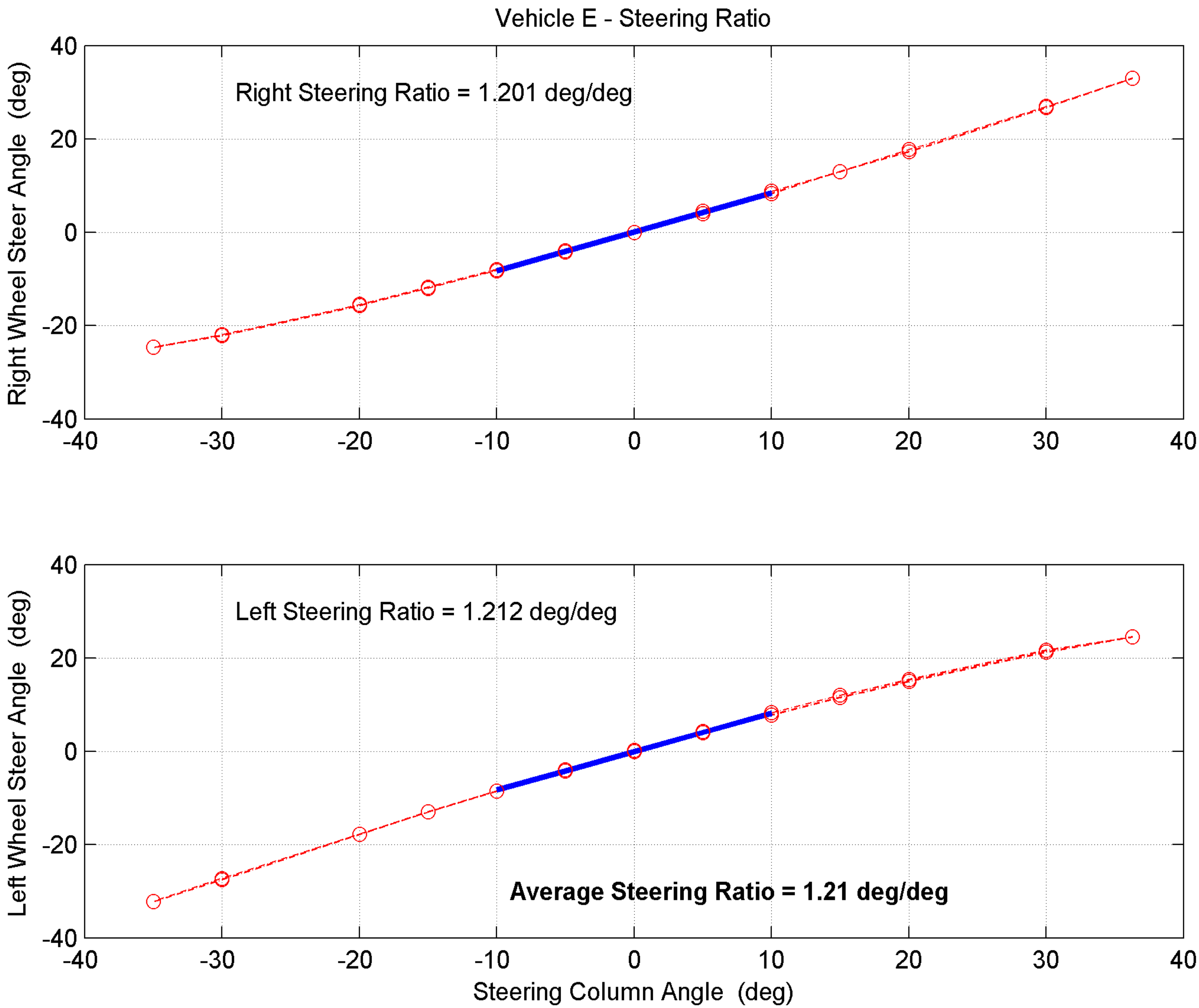
Representative Sine Sweep Time Domain Plots - Vehicle E
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)



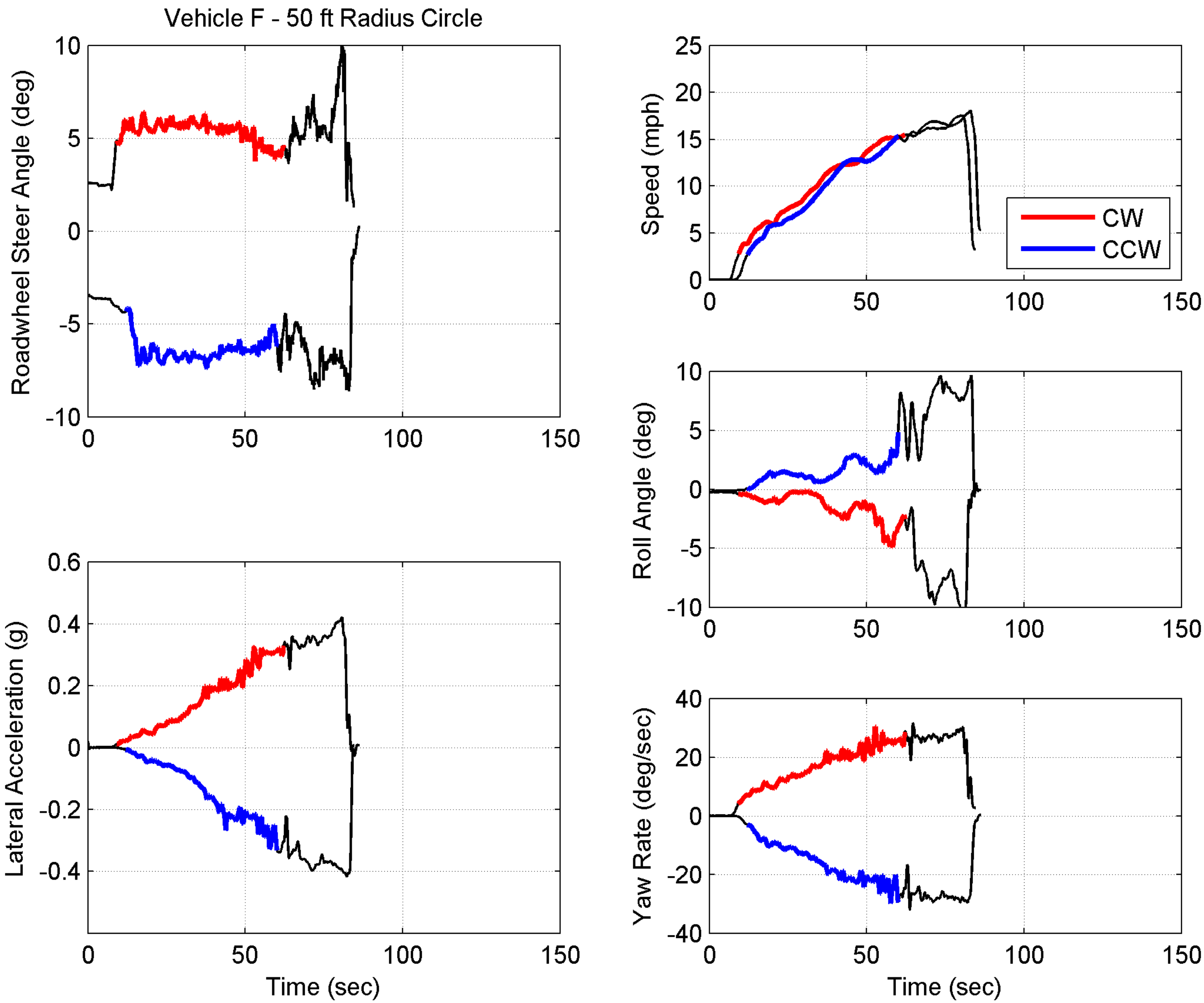
Vehicle E
15 mph Frequency Response
Ay Mag. (g/deg)
0.06
0.05
0.04
0.03
0.02
0.01
10^0
Roll Angle Mag. (deg/deg)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10^0
Ay Phase (deg)
50
0
-50
-100
-150
-200
10^0
Frequency (Hz)
Roll Angle Phase (deg)
-200
-220
-240
-260
-280
-300
-320
10^0
Frequency (Hz)

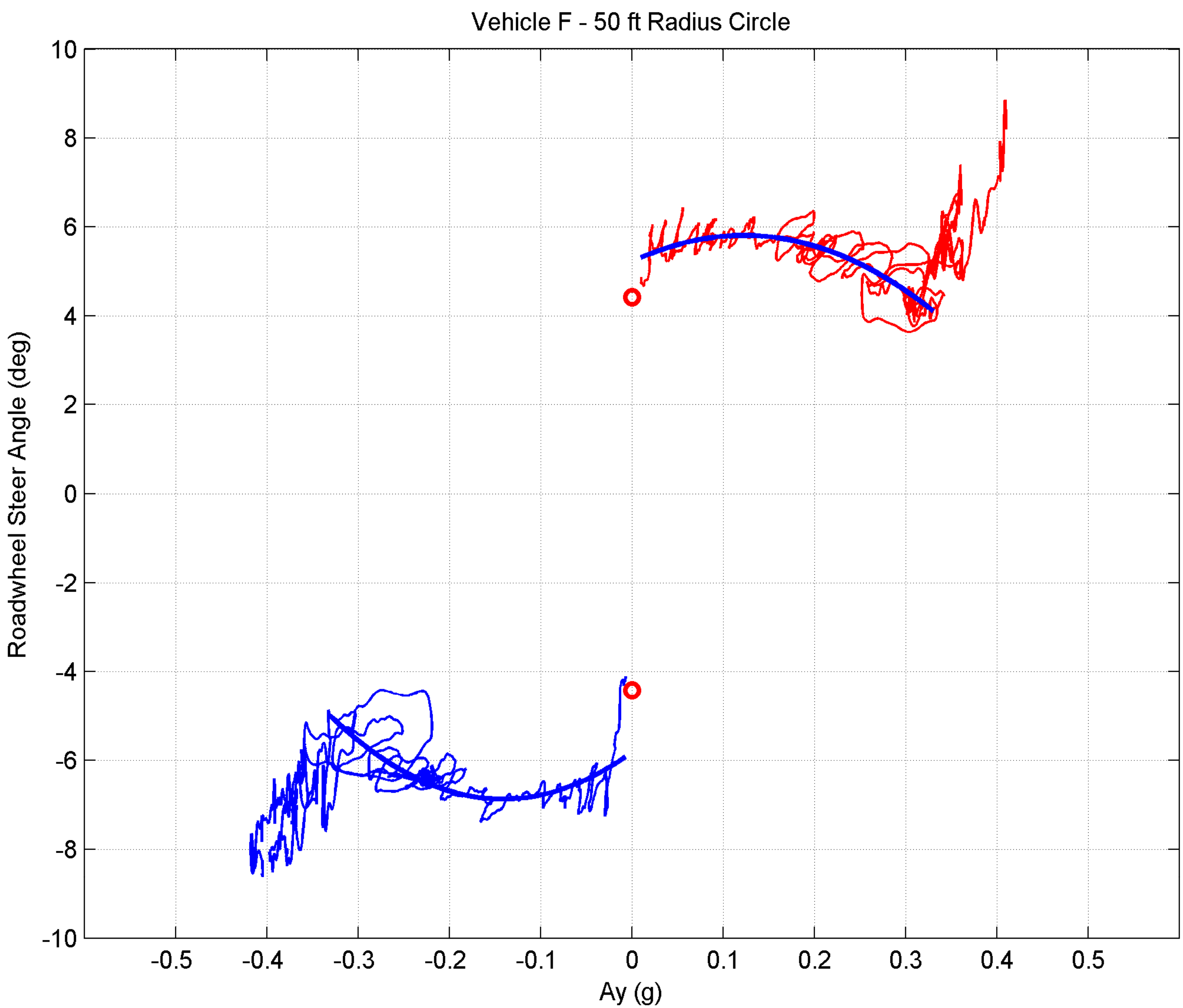


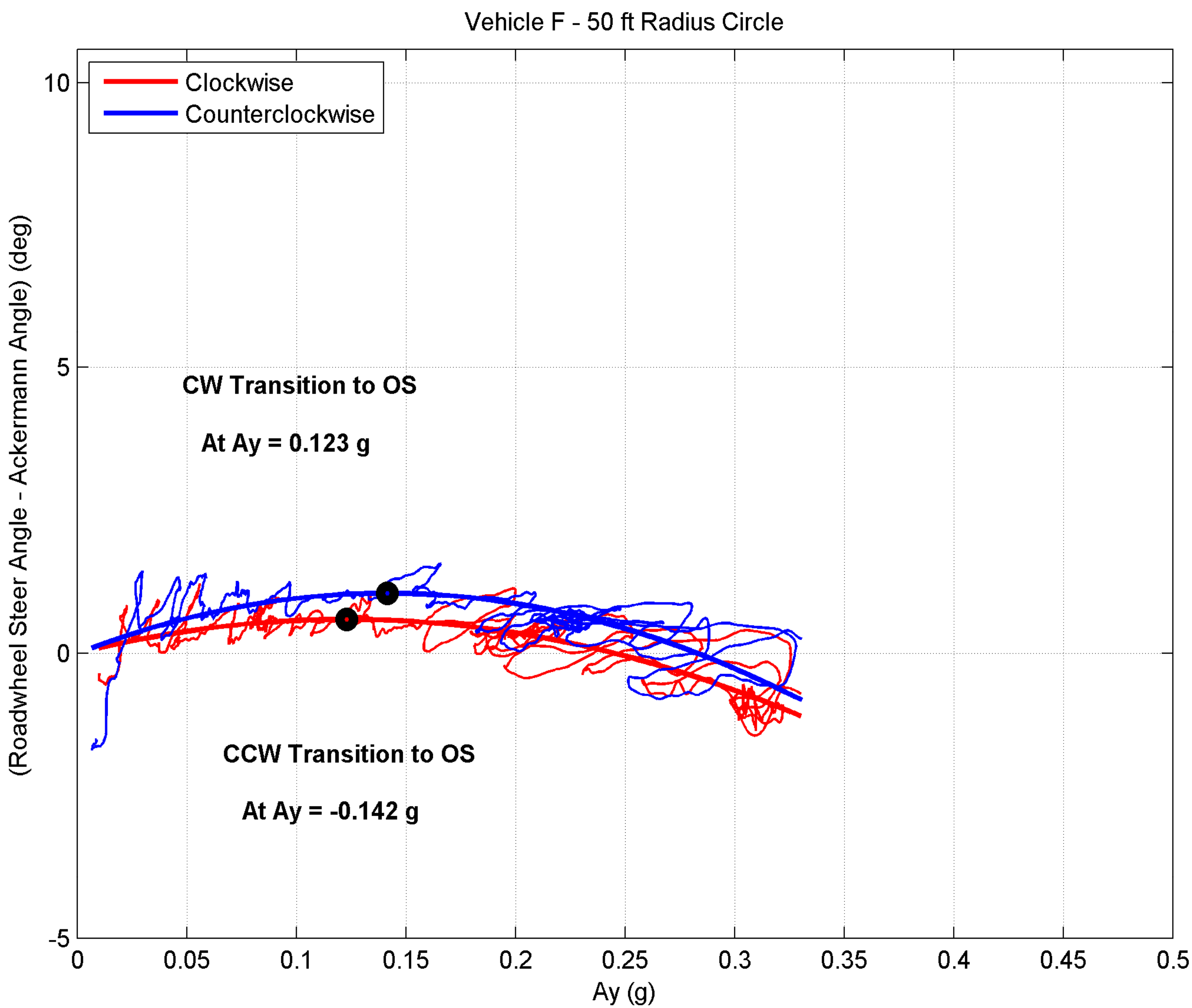
Vehicle E
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
4
3.5
3
2.5
2
1.5
1
10^0
Yaw Rate Mag. (deg/sec)/deg
6
5.5
5
4.5
4
3.5
3
10^0
Roll Rate Phase (deg)
-100
-120
-140
-160
-180
-200
-220
10^0
Frequency (Hz)
Yaw Rate Phase (deg)
0
-20
-40
-60
-80
-100
10^0
Frequency (Hz)



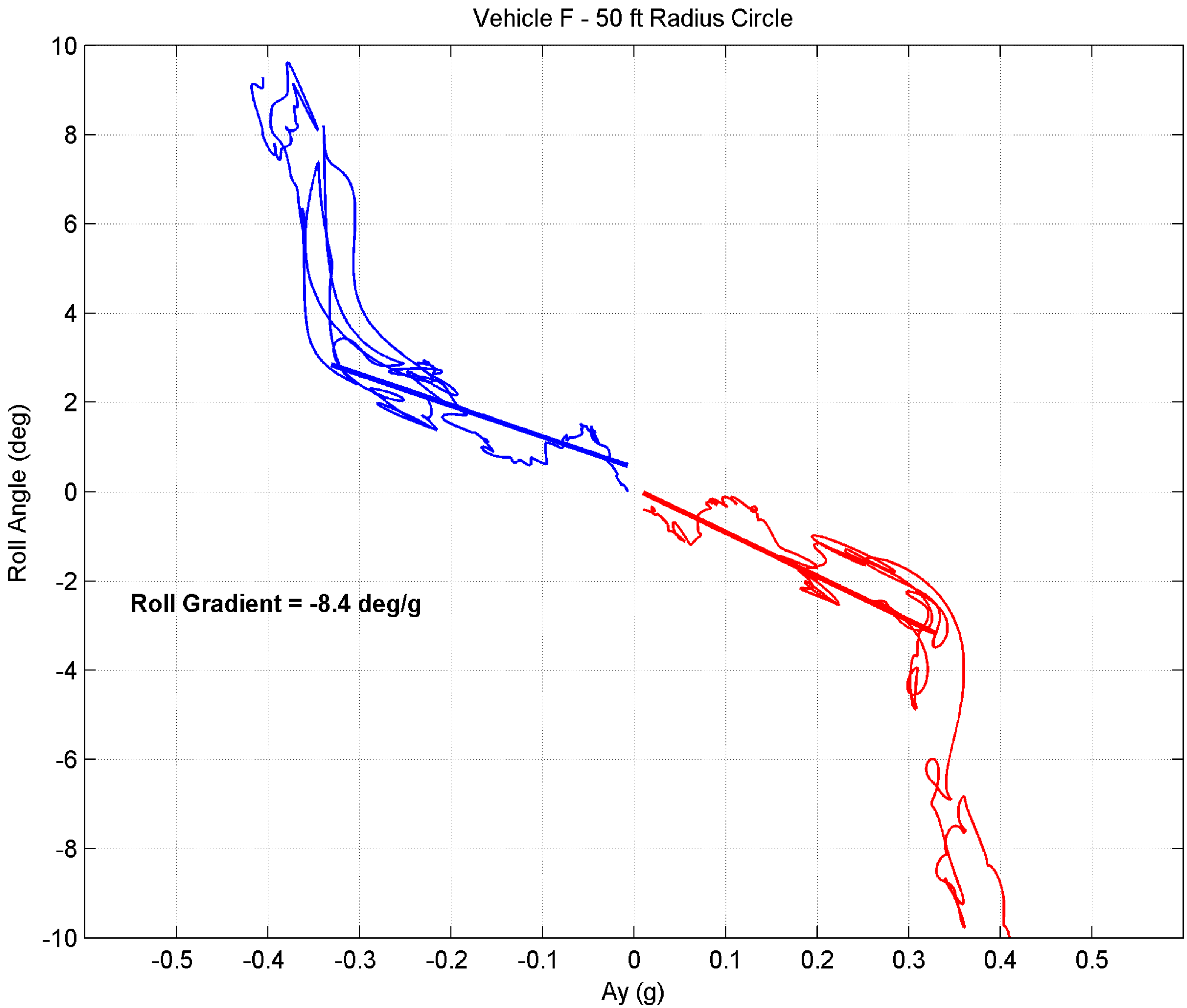
Vehicle E - Steering Ratio
Right Steering Ratio = 1.201 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-40
-30
-20
-10
0
10
20
30
40
Left Steering Ratio = 1.212 deg/deg
Average Steering Ratio = 1.21 deg/deg
Left Wheel Steer Angle (deg)
Steering Column Angle (deg)


Vehicle F - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
5
0
-5
-10
0
50
100
150
Speed (mph)
25
20
15
10
5
0
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

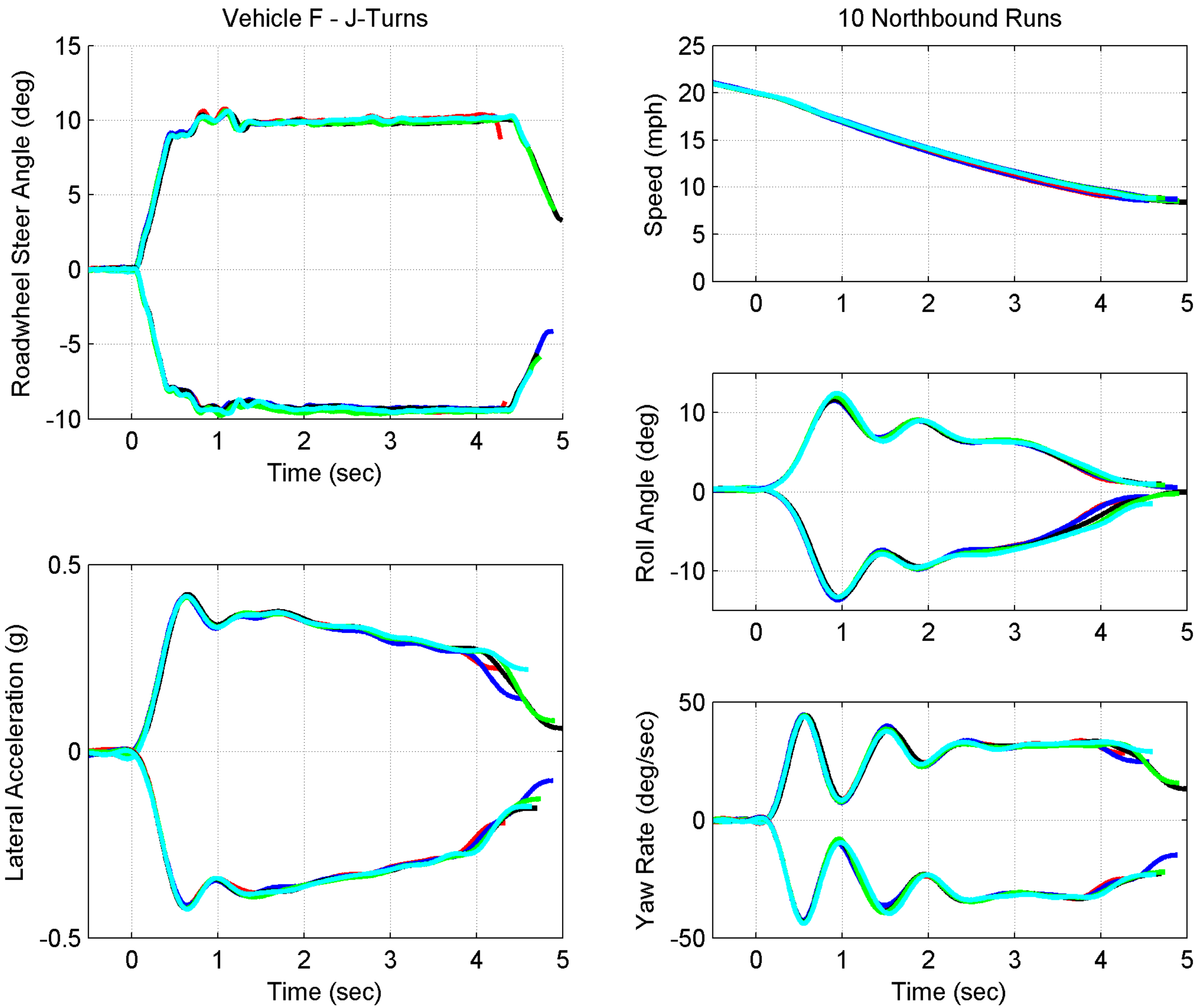

Vehicle F - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

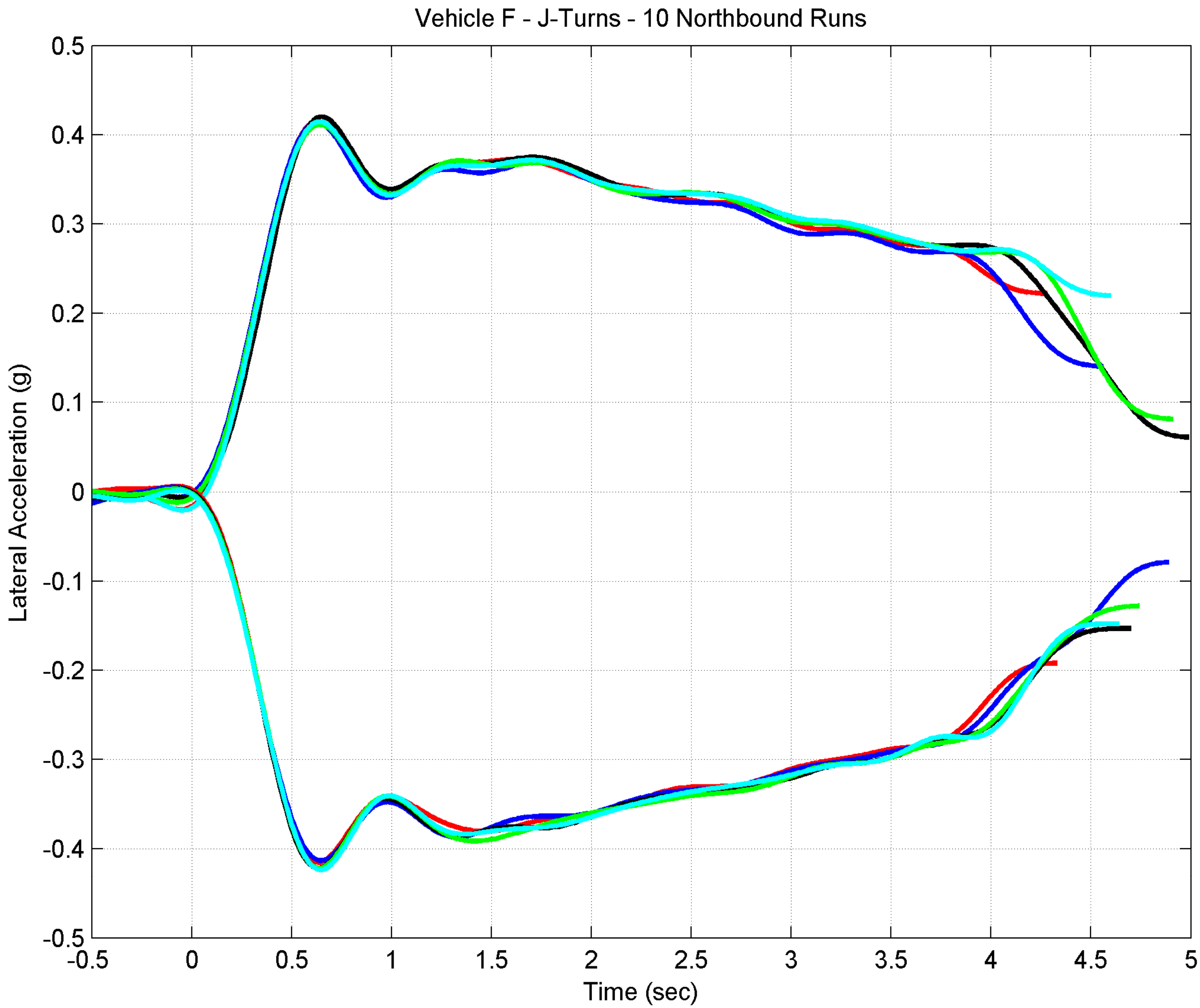


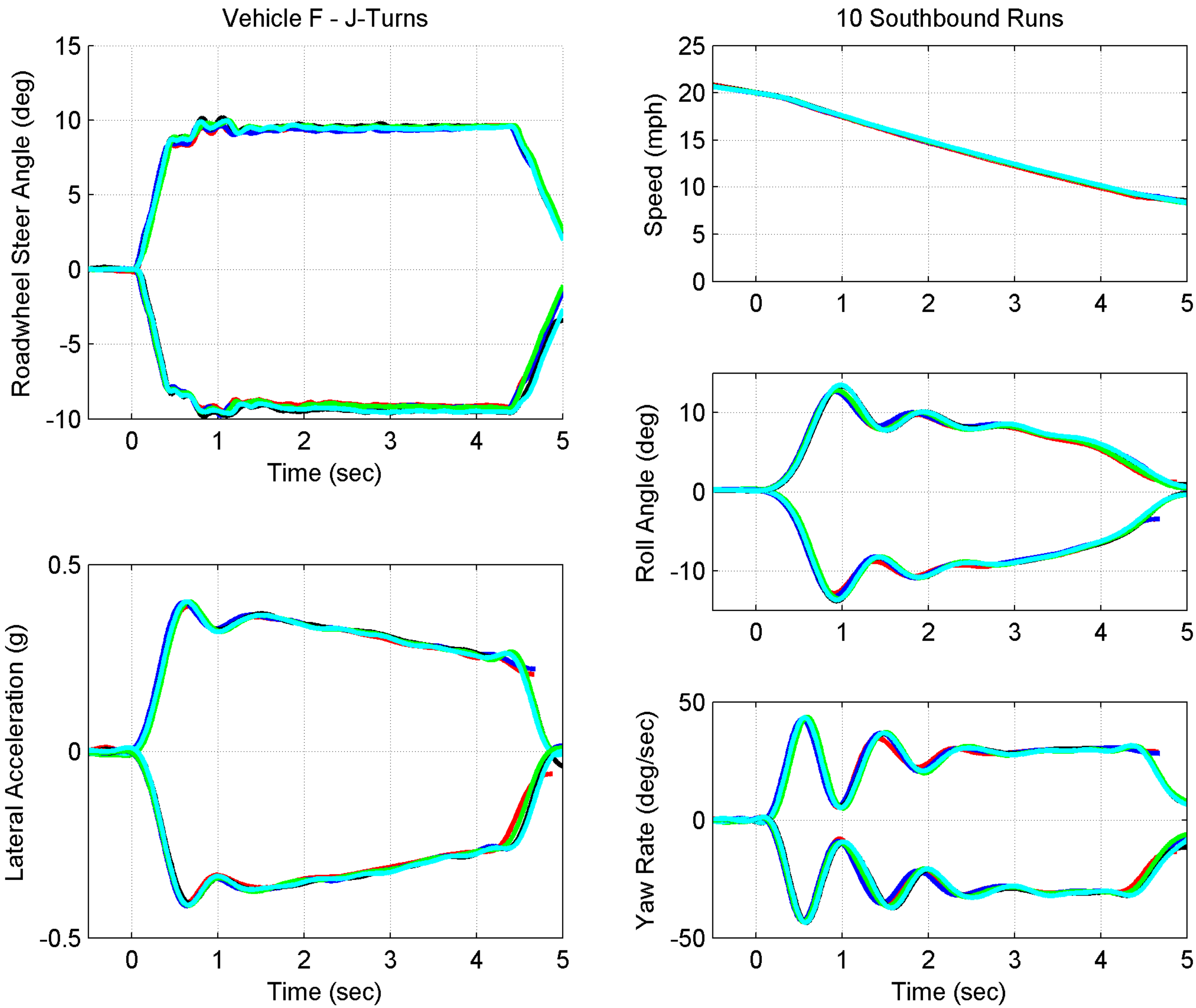
Vehicle F - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.123 g
CCW Transition to OS
At Ay = -0.142 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

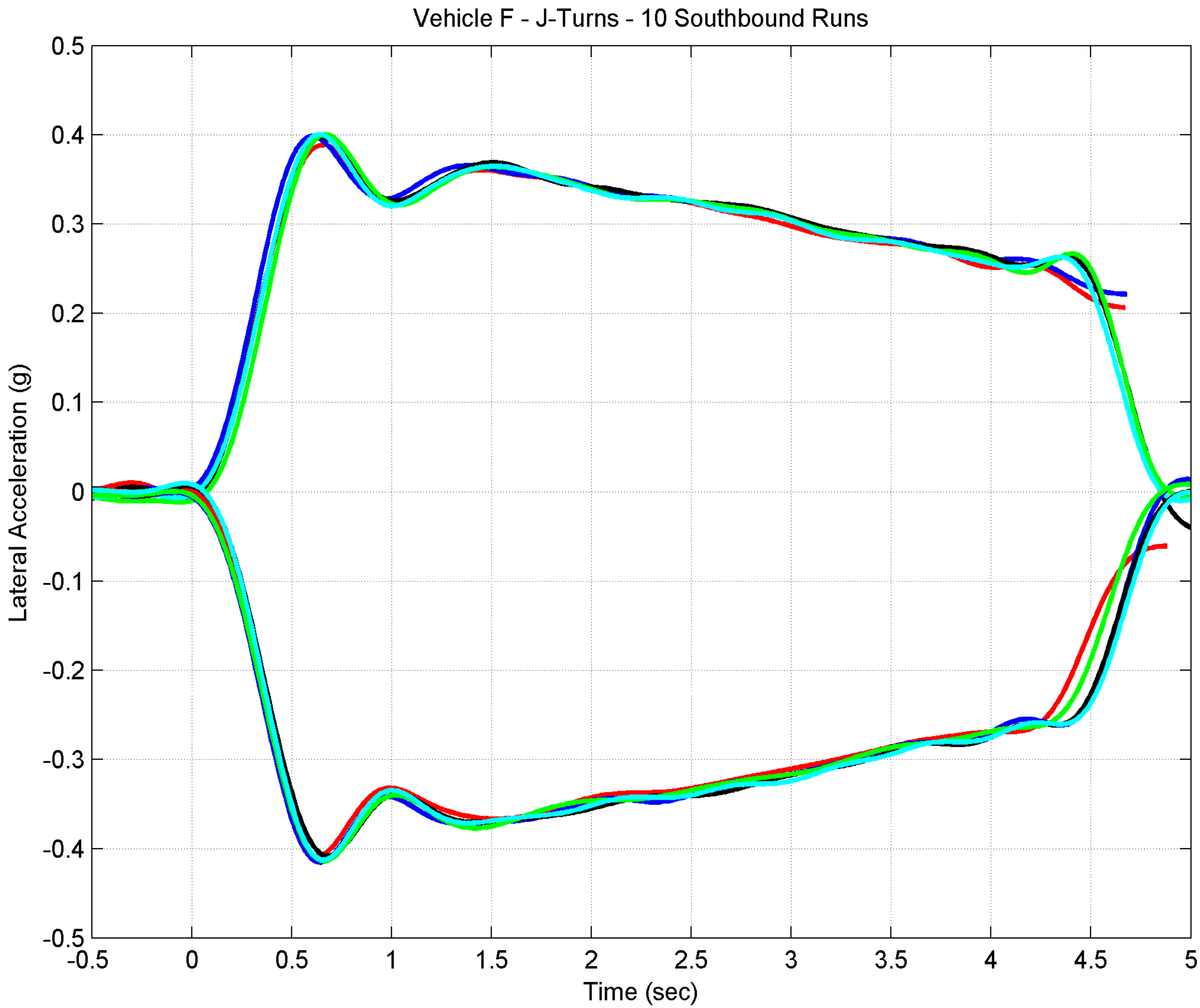


Vehicle F - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -8.4 deg/g
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5


Vehicle F - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle F - J-Turns - 10 Northbound Runs
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle F - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)


Vehicle F - J-Turns - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle F

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.4154	-0.4154
2	0.4144	-0.4133
3	0.4203	-0.4218
4	0.4115	-0.4220
5	0.4148	-0.4236
Mean Value of 5 Runs	0.4153	-0.4192
Standard Deviation of 5 Runs	0.003	0.005

Average of 10 Northbound Runs

0.4172

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.3886	-0.4082
2	0.3985	-0.4153
3	0.3975	-0.4083
4	0.4005	-0.4138
5	0.4005	-0.4127
Mean Value of 5 Runs	0.3971	-0.4117
Standard Deviation of 5 Runs	0.005	0.003

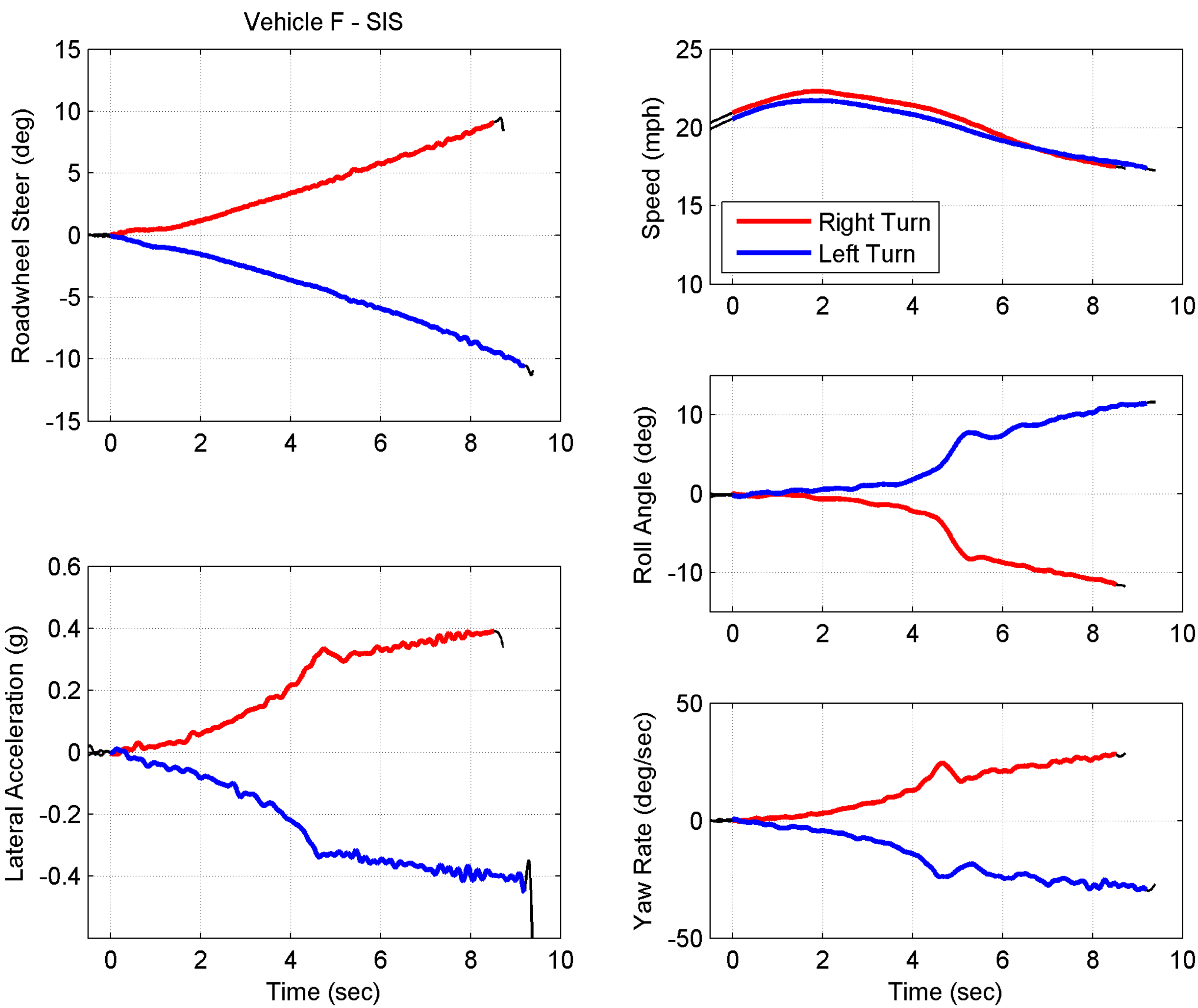
Average of 10 Southbound Runs

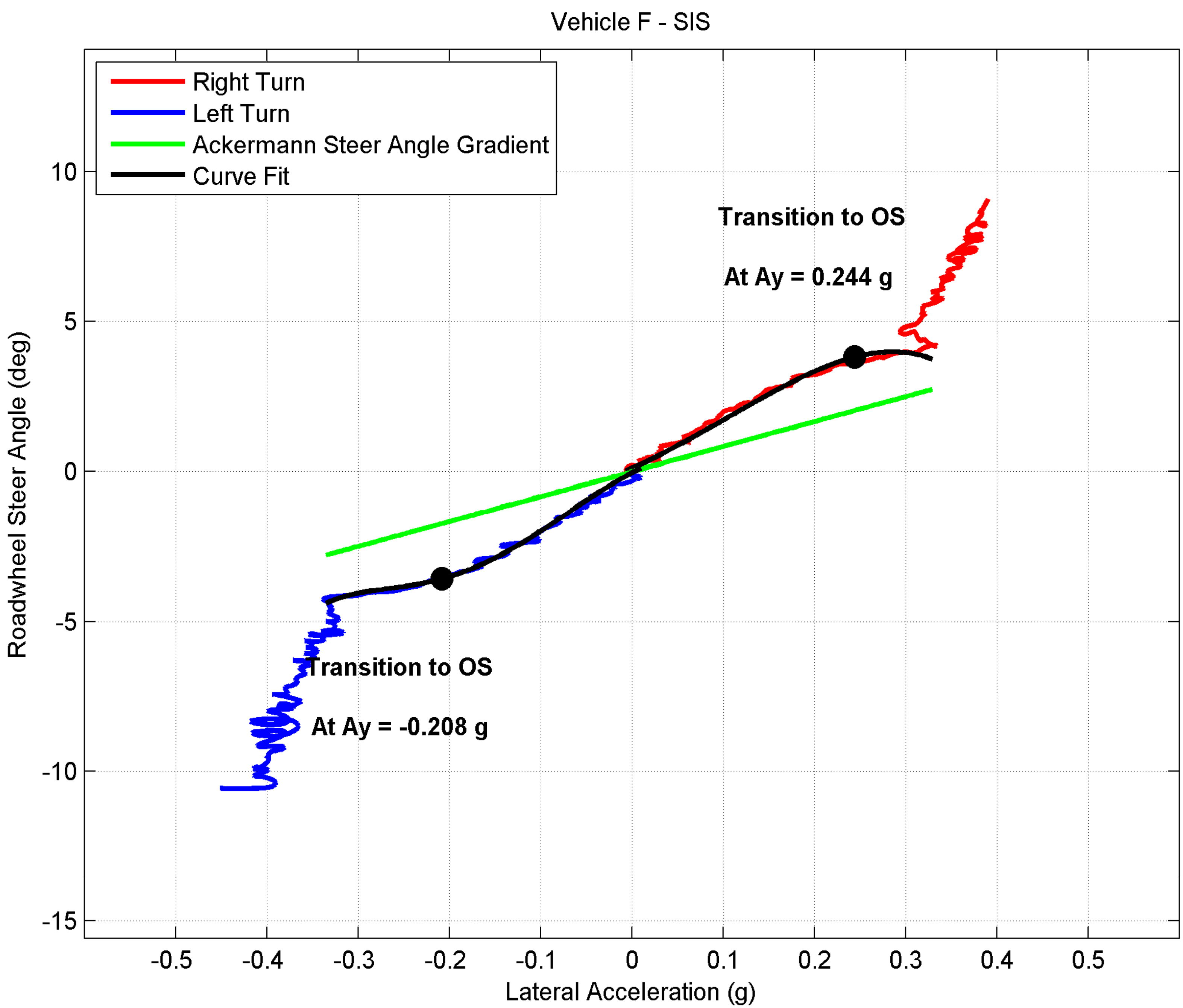
0.4044

Average of All 20 Runs

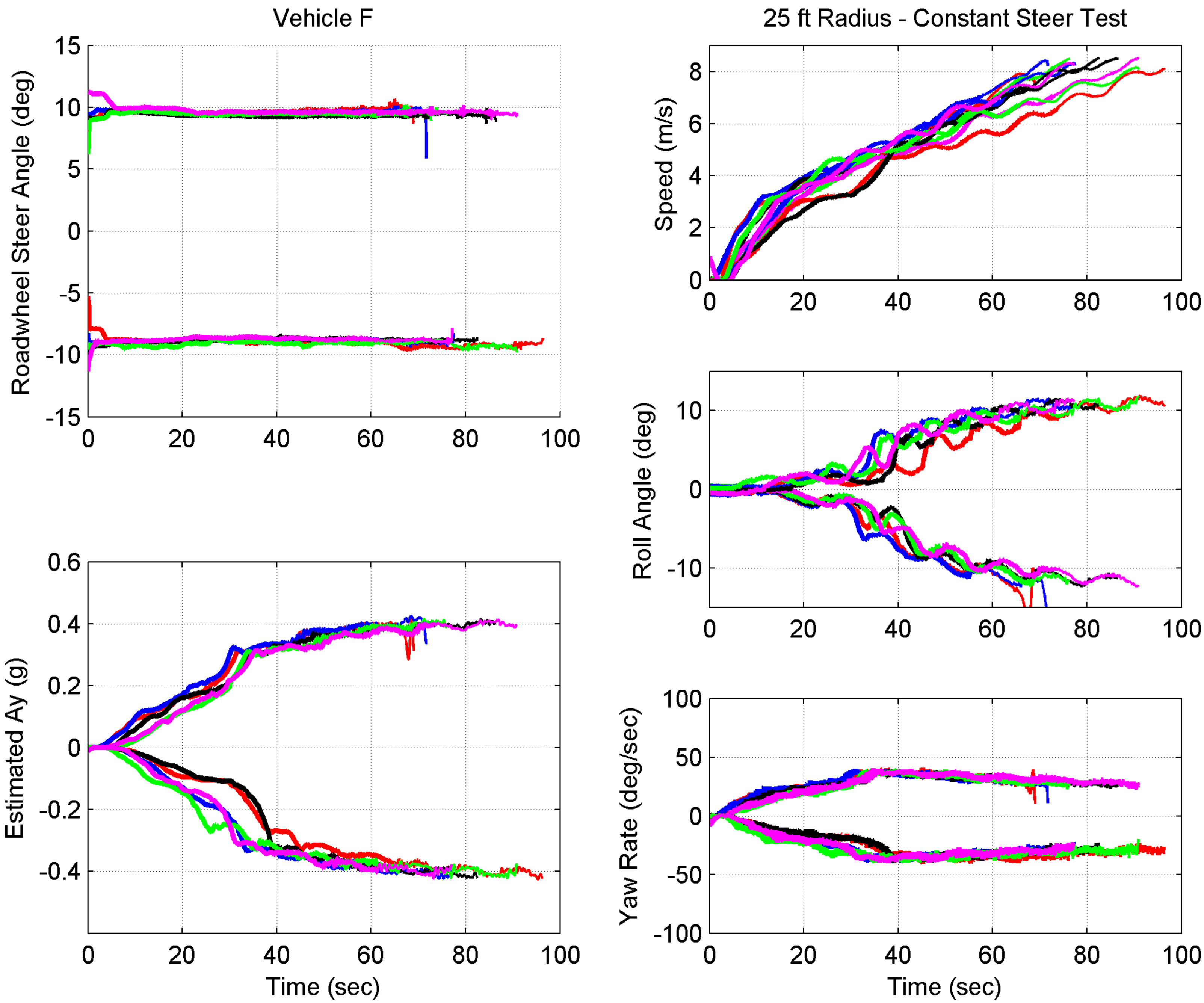
0.411

Threshold Ay

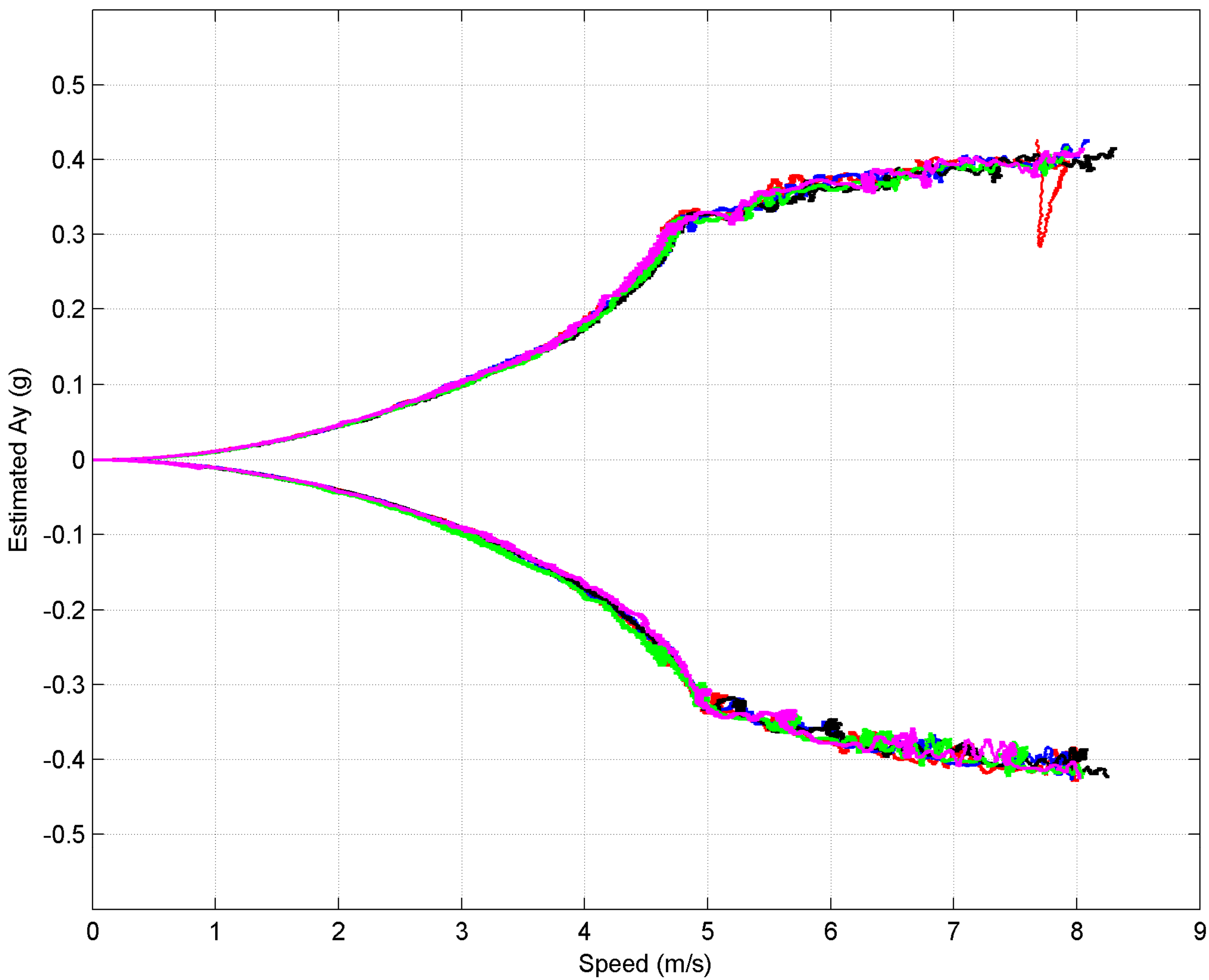

Vehicle F - SIS
Roadwheel Steer (deg)
15
10
5
0
-5
-10
-15
0 2 4 6 8 10
Speed (mph)
25
20
15
10
0 2 4 6 8 10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
0 2 4 6 8 10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0 2 4 6 8 10
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
0 2 4 6 8 10
Time (sec)

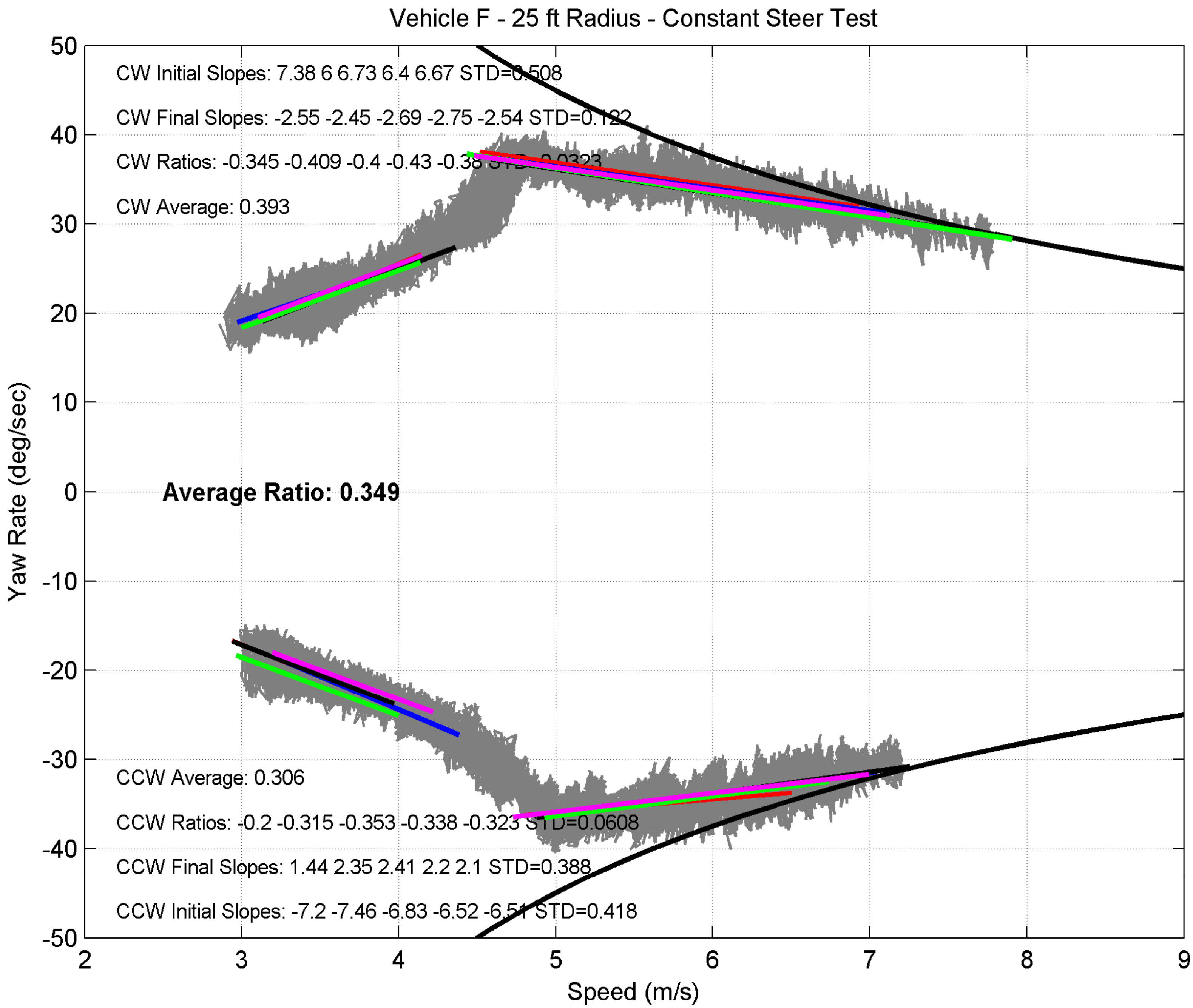


Vehicle F - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to OS
At Ay = 0.244 g
Transition to OS
At Ay = -0.208 g
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

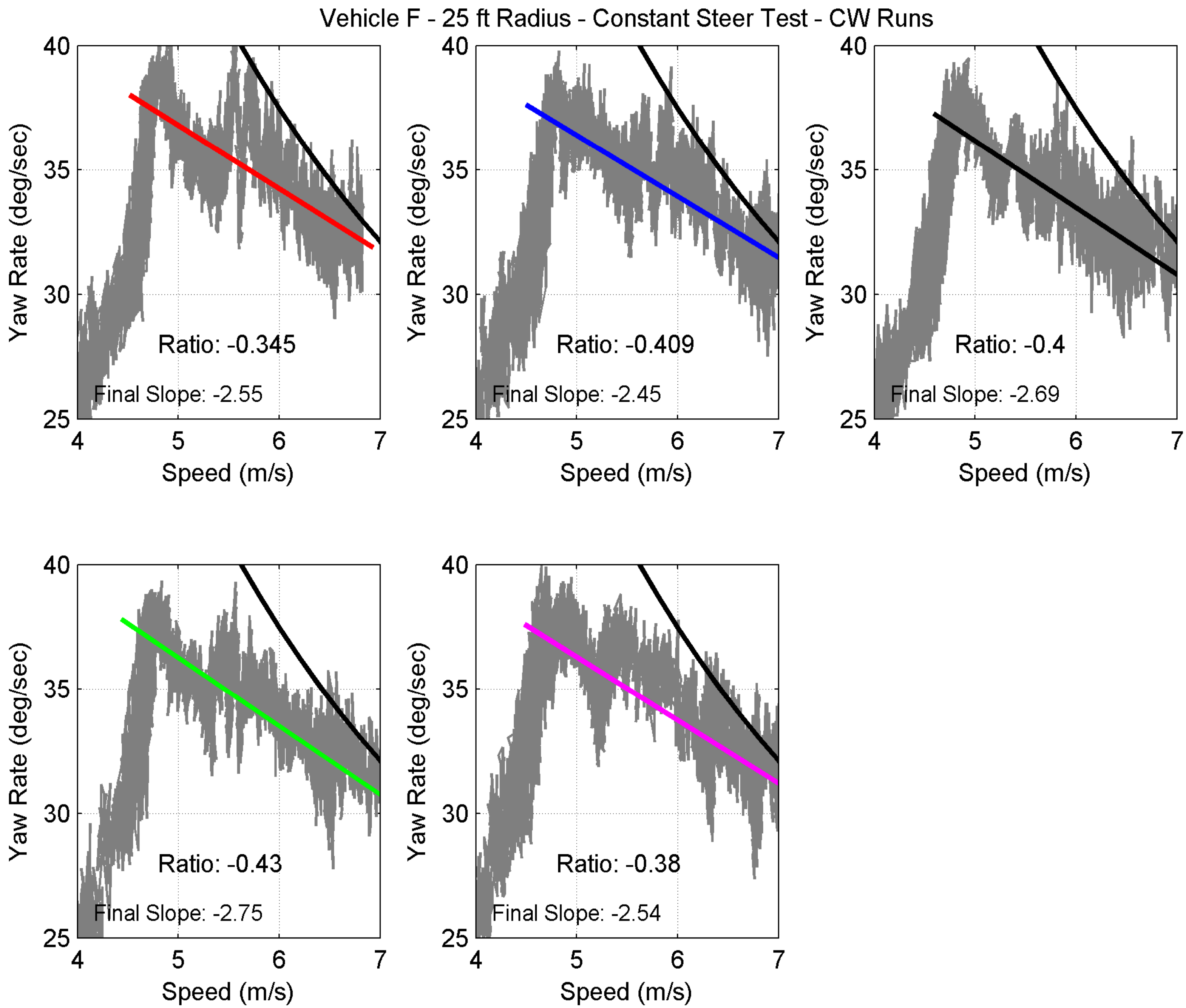

Vehicle F
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

Vehicle F - 25 ft Radius - Constant Steer Test

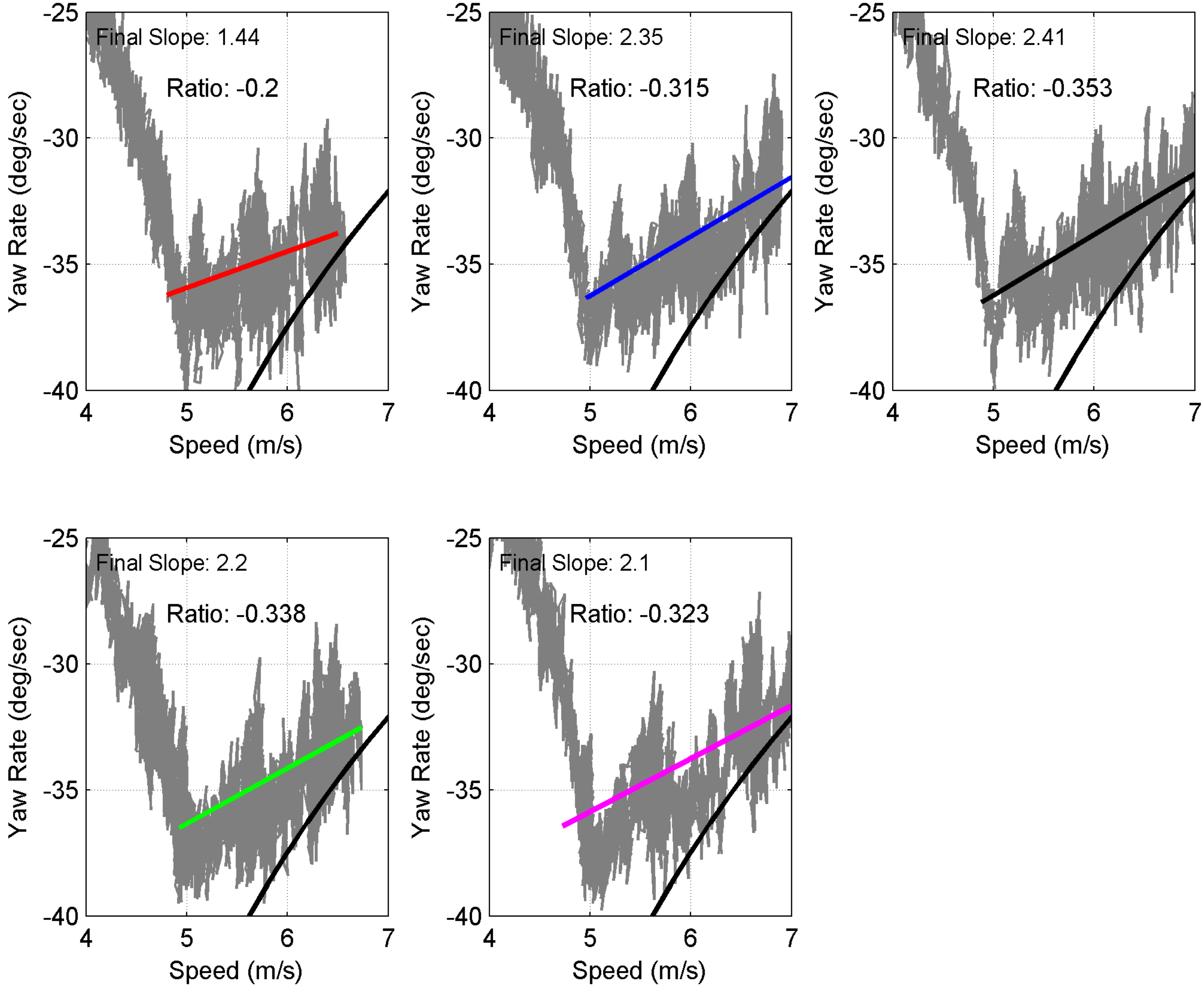




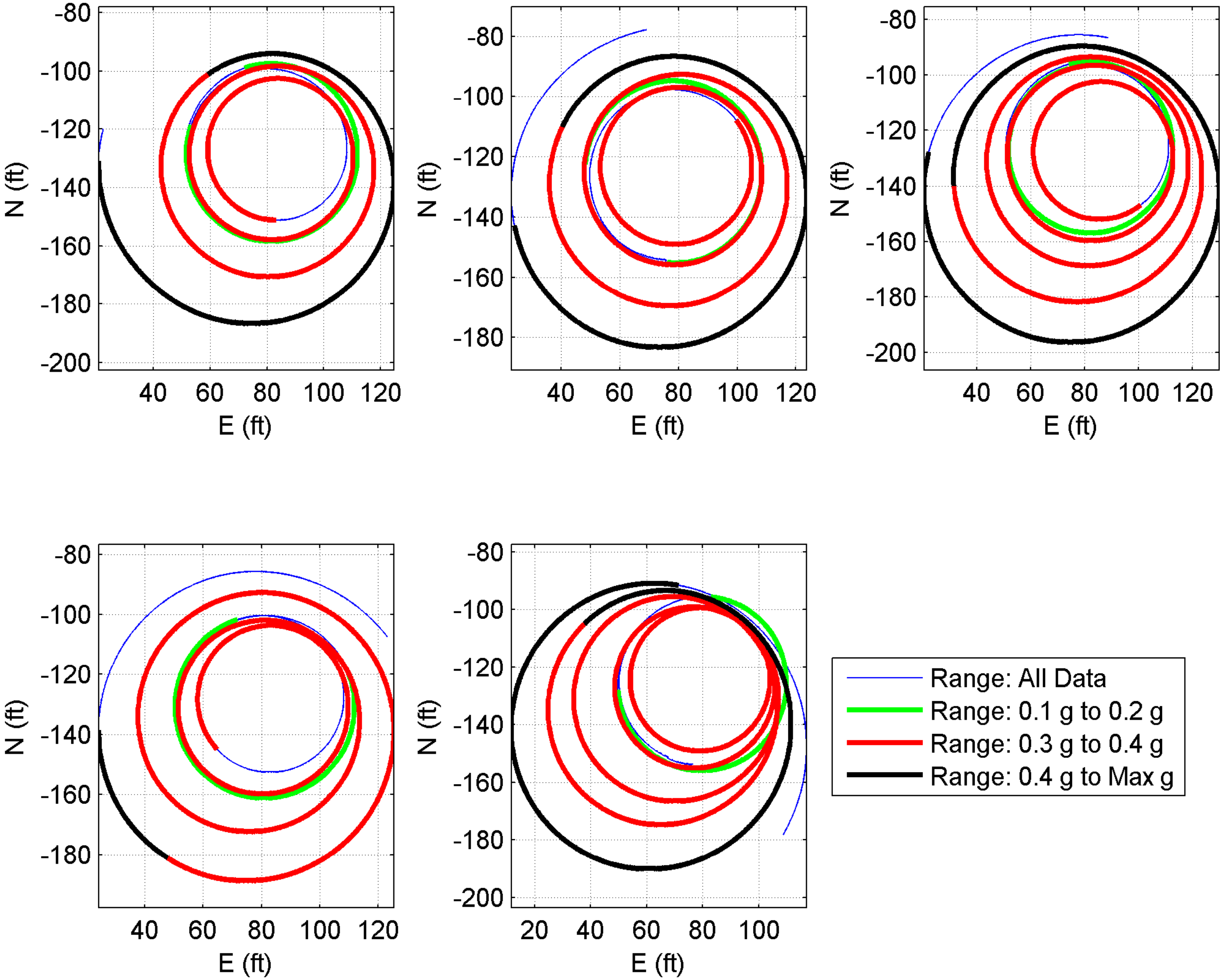
Vehicle F - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 7.38 6 6.73 6.4 6.67 STD=0.508
CW Final Slopes: -2.55 -2.45 -2.69 -2.75 -2.54 STD=0.122
CW Ratios: -0.345 -0.409 -0.4 -0.43 -0.38 STD=0.0323
CW Average: 0.393
Average Ratio: 0.349
CCW Average: 0.306
CCW Ratios: -0.2 -0.315 -0.353 -0.338 -0.323 STD=0.0608
CCW Final Slopes: 1.44 2.35 2.41 2.2 2.1 STD=0.388
CCW Initial Slopes: -7.2 -7.46 -6.83 -6.52 -6.51 STD=0.418
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8
9


Vehicle F - 25 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: -0.345
Final Slope: -2.55
Ratio: -0.409
Final Slope: -2.45
Ratio: -0.4
Final Slope: -2.69
Ratio: -0.43
Final Slope: -2.75
Ratio: -0.38
Final Slope: -2.54

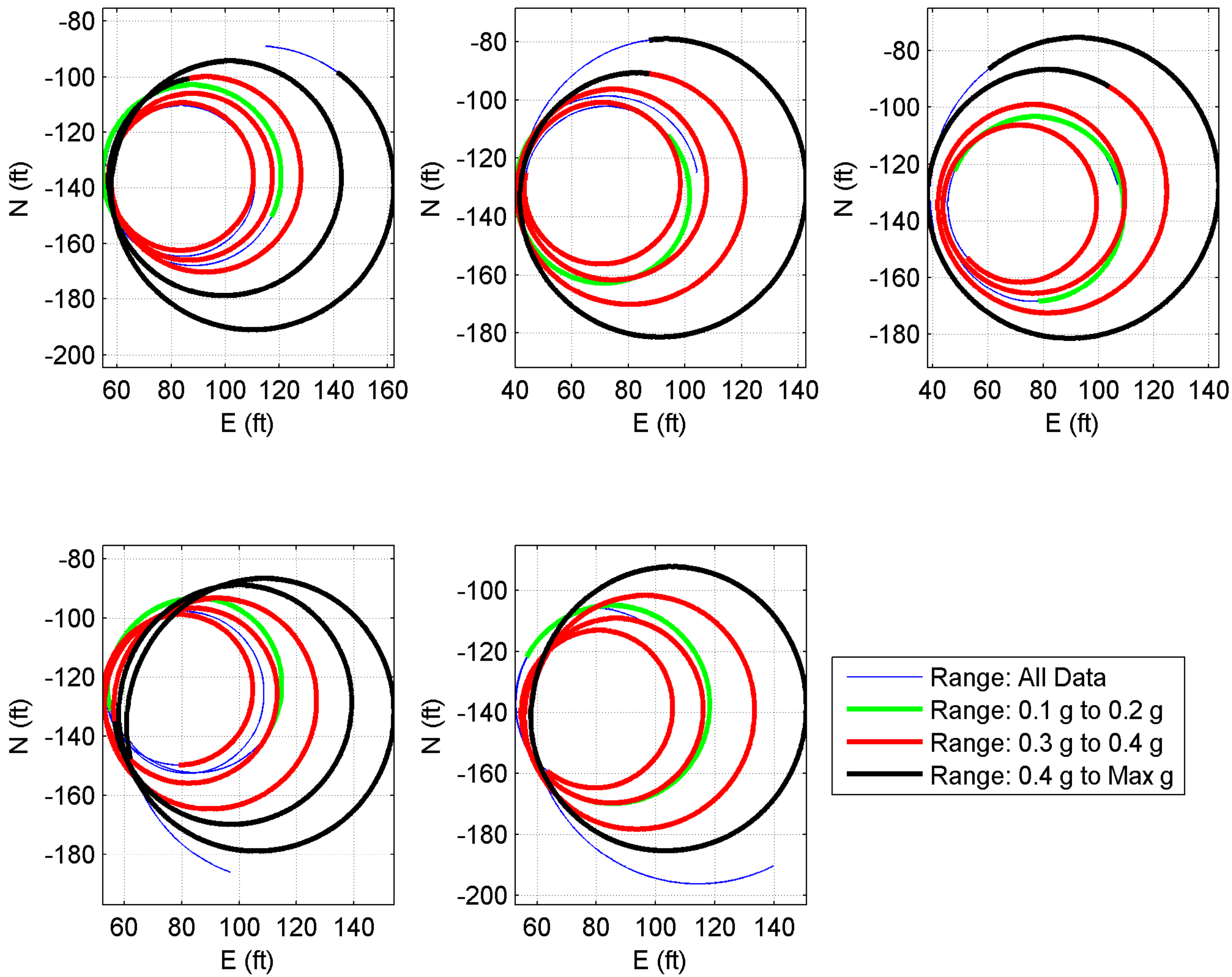
Vehicle F - 25 ft Radius - Constant Steer Test - CCW Runs

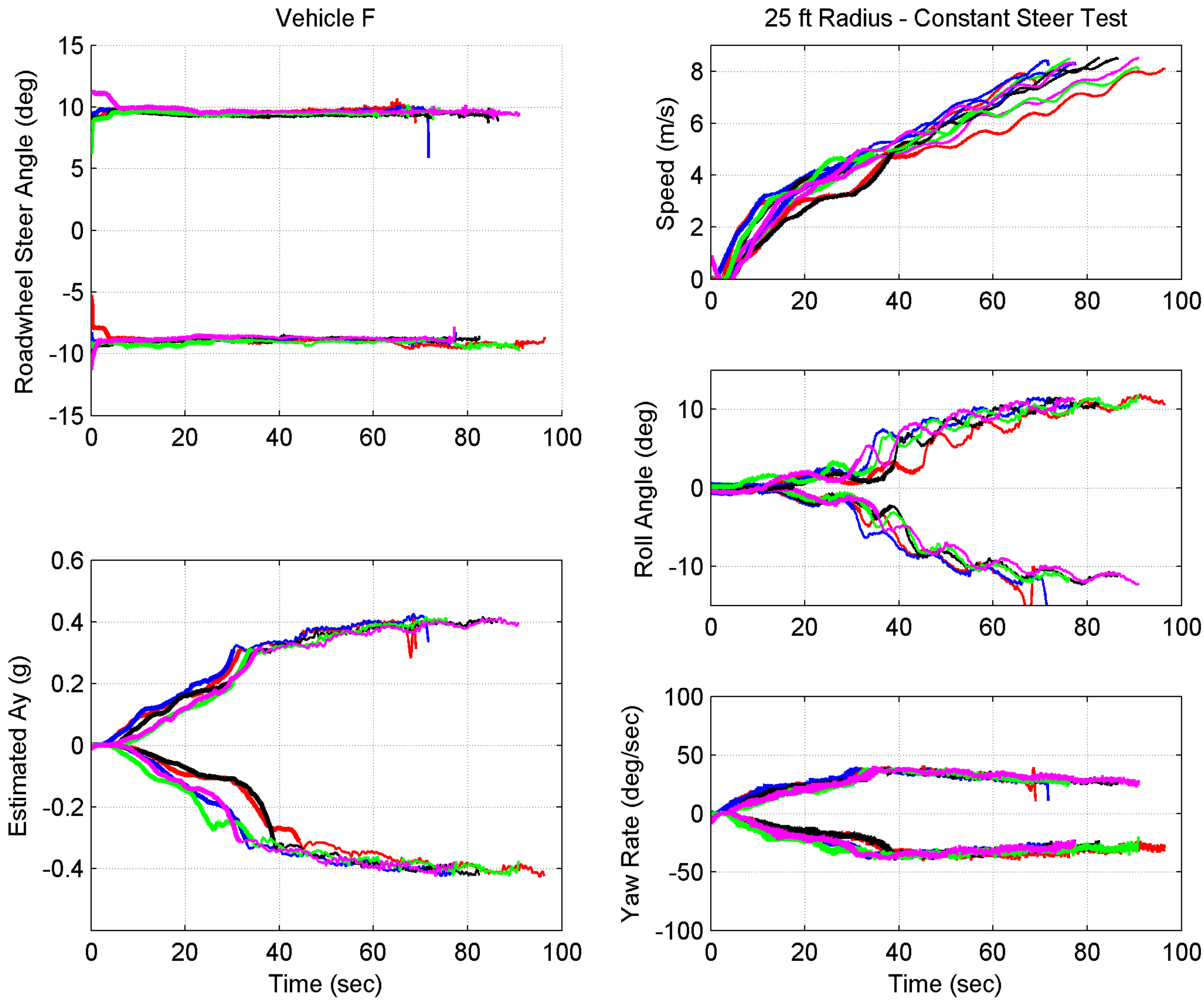


Vehicle F - 25 ft Radius - Constant Steer Test - CW Runs

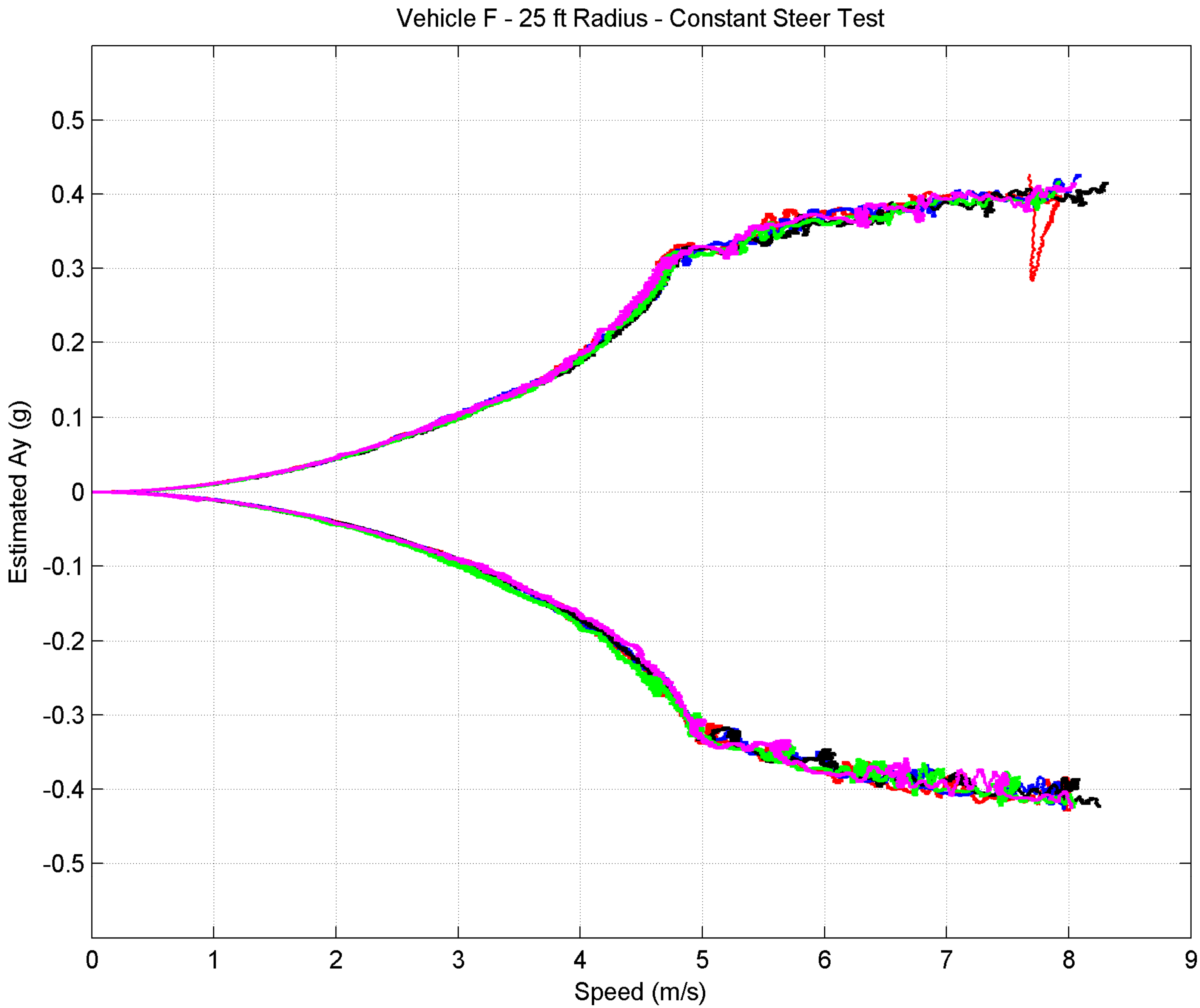


Vehicle F - 25 ft Radius - Constant Steer Test - CCW Runs

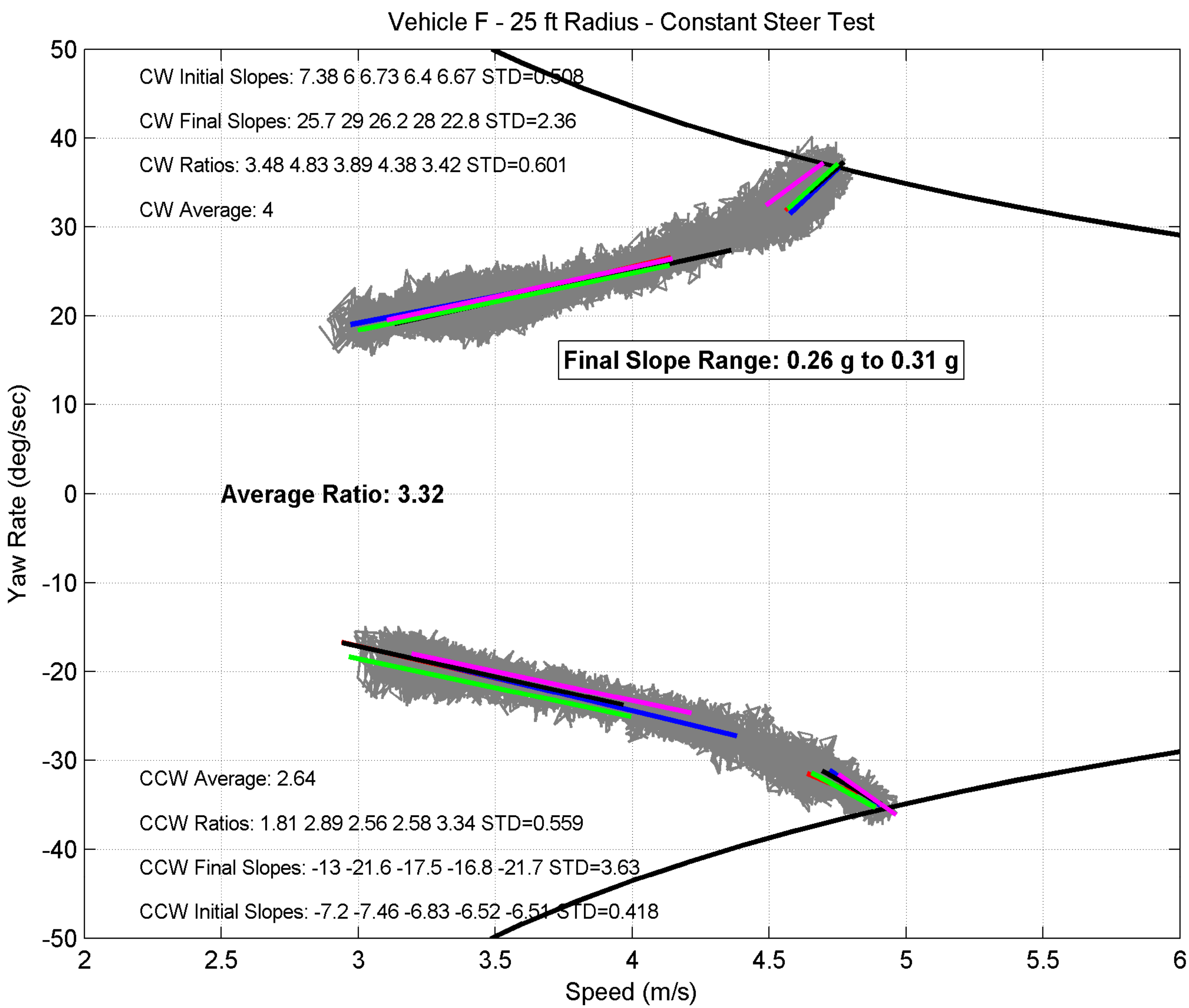


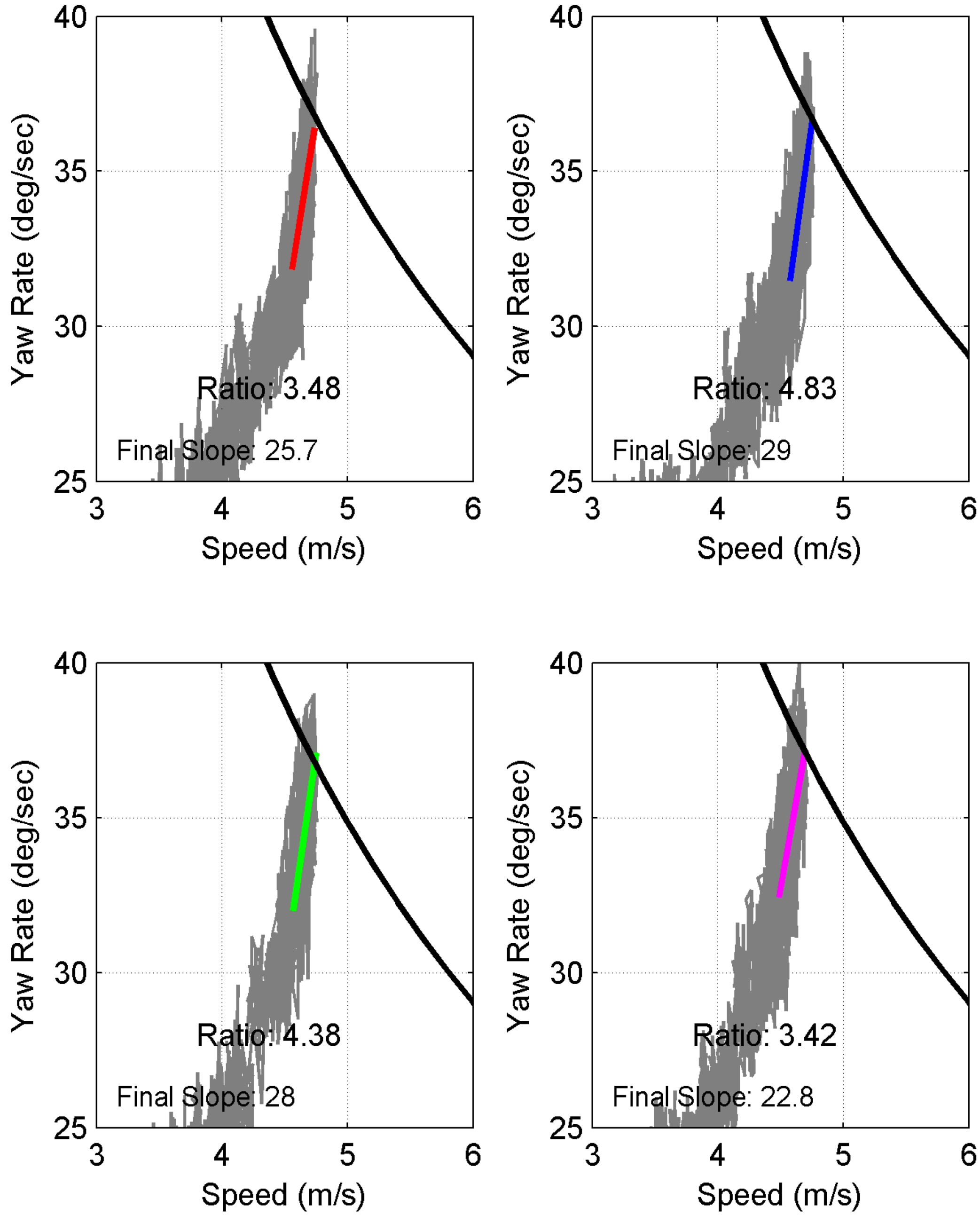


Vehicle F
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



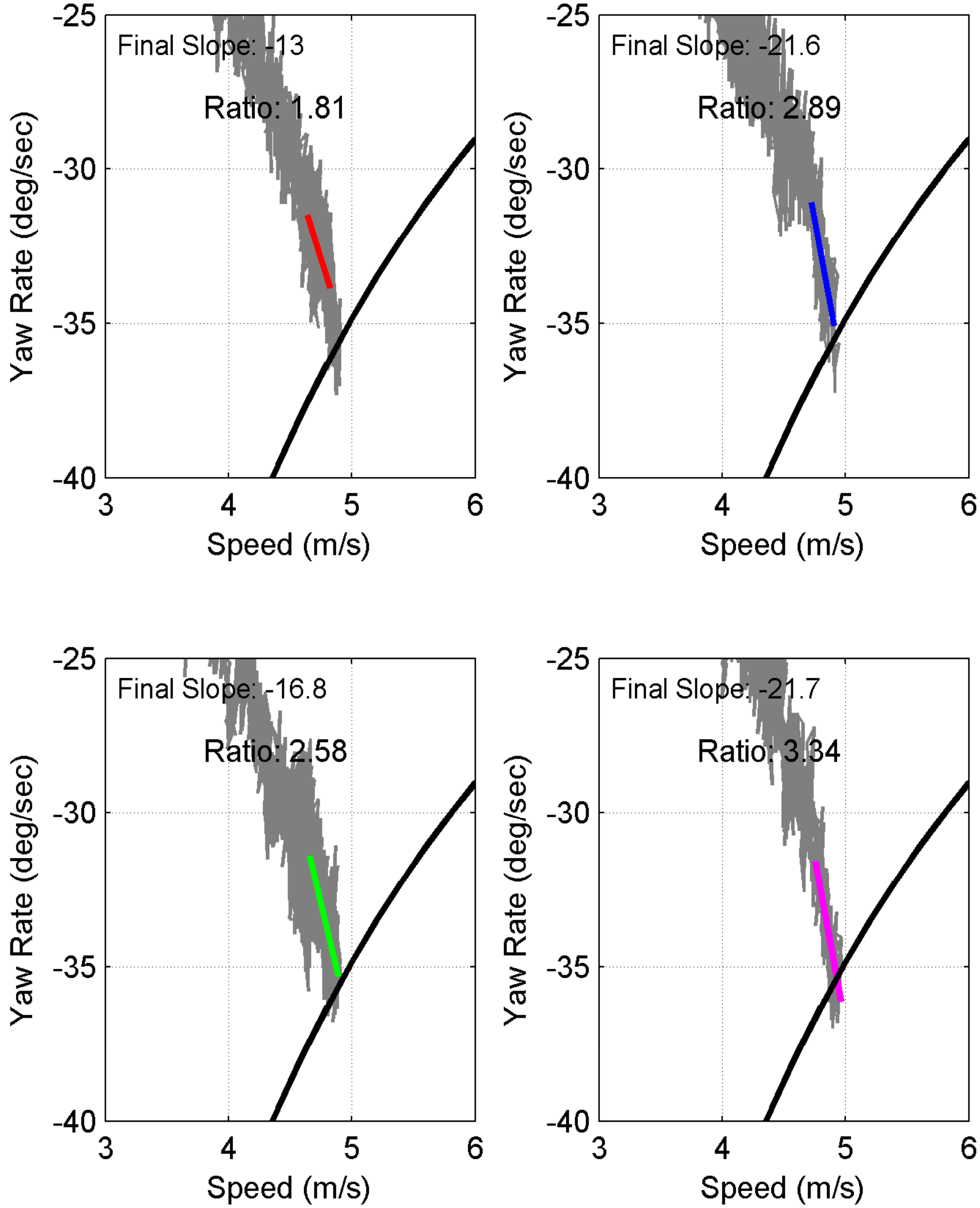
Vehicle F - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9


Vehicle F - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 7.38 6 6.73 6.4 6.67 STD=0.508
CW Final Slopes: 25.7 29 26.2 28 22.8 STD=2.36
CW Ratios: 3.48 4.83 3.89 4.38 3.42 STD=0.601
CW Average: 4
Final Slope Range: 0.26 g to 0.31 g
Average Ratio: 3.32
CCW Average: 2.64
CCW Ratios: 1.81 2.89 2.56 2.58 3.34 STD=0.559
CCW Final Slopes: -13 -21.6 -17.5 -16.8 -21.7 STD=3.63
CCW Initial Slopes: -7.2 -7.46 -6.83 -6.52 -6.51 STD=0.418
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
2.5
3
3.5
4
4.5
5
5.5
6



Final Slope Range:

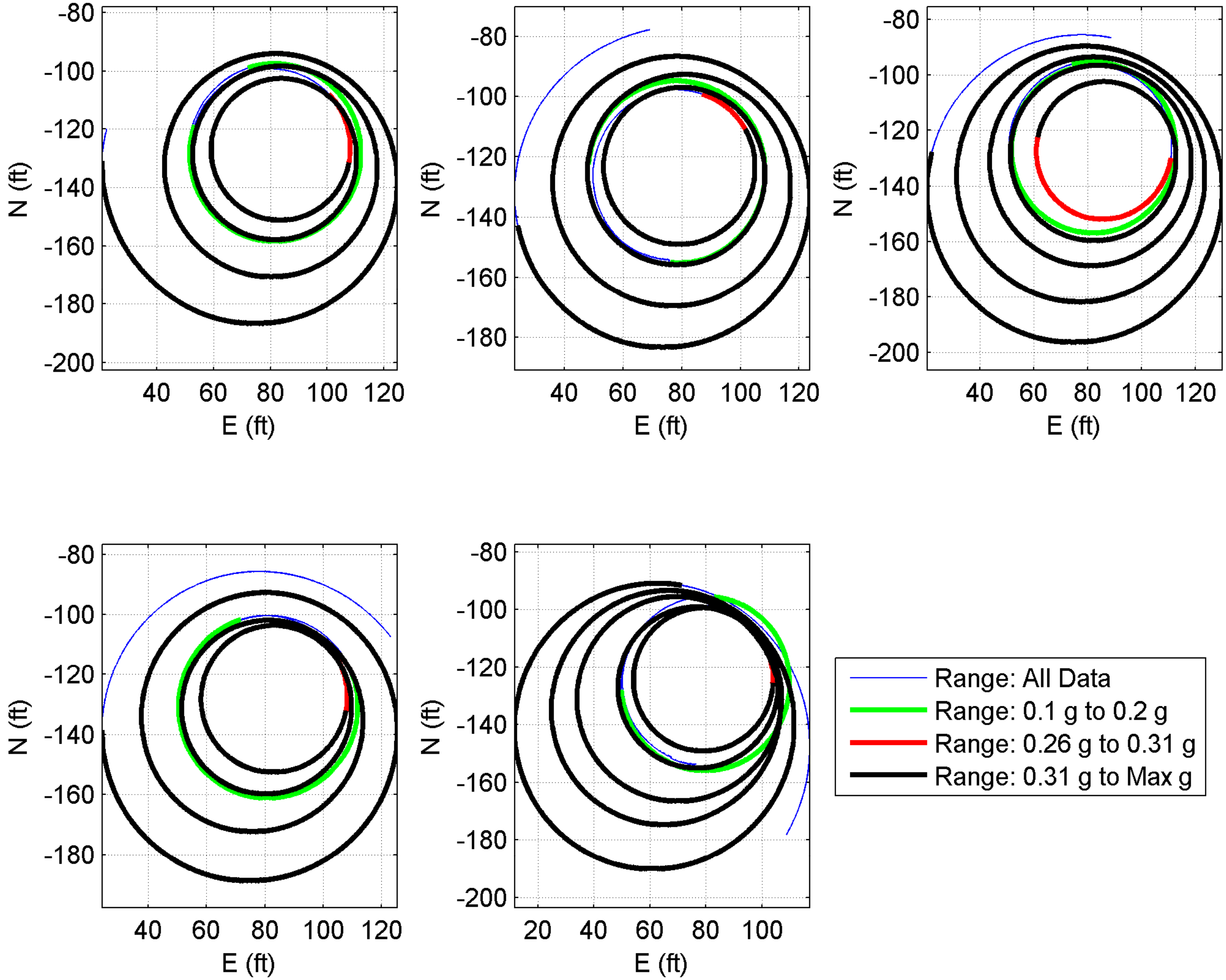
0.26 g to 0.31 g

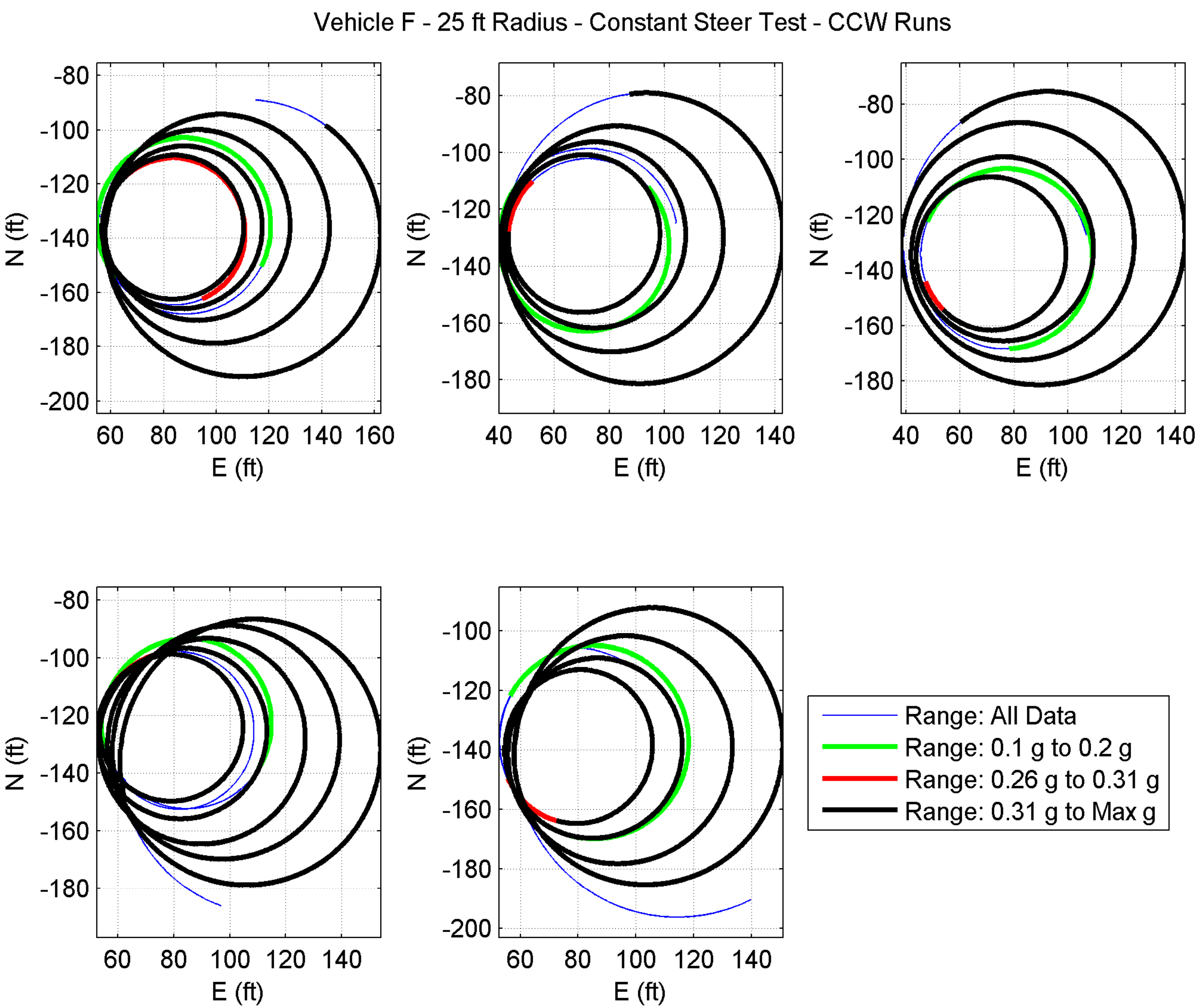


Final Slope Range:

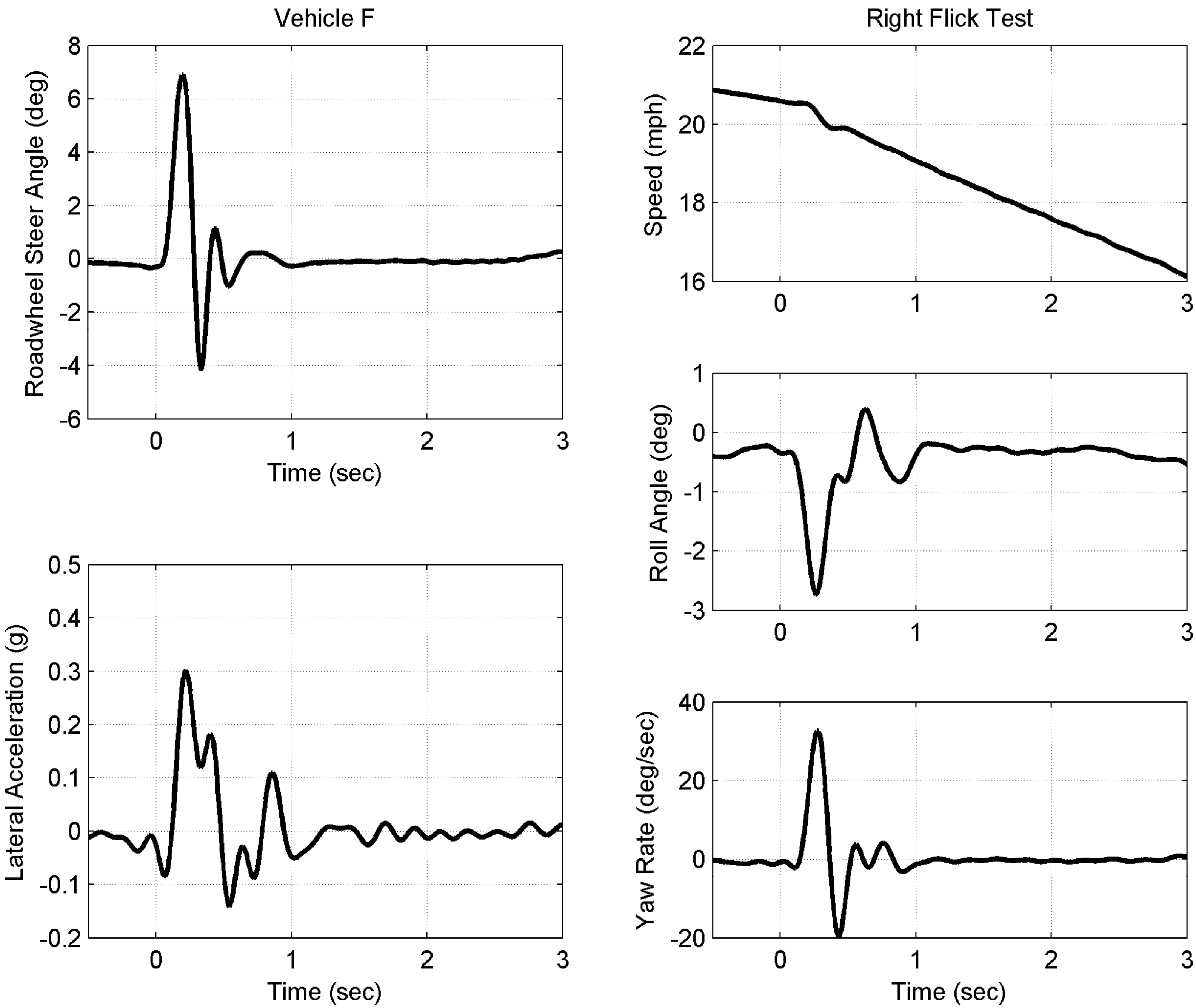
0.26 g to 0.31 g

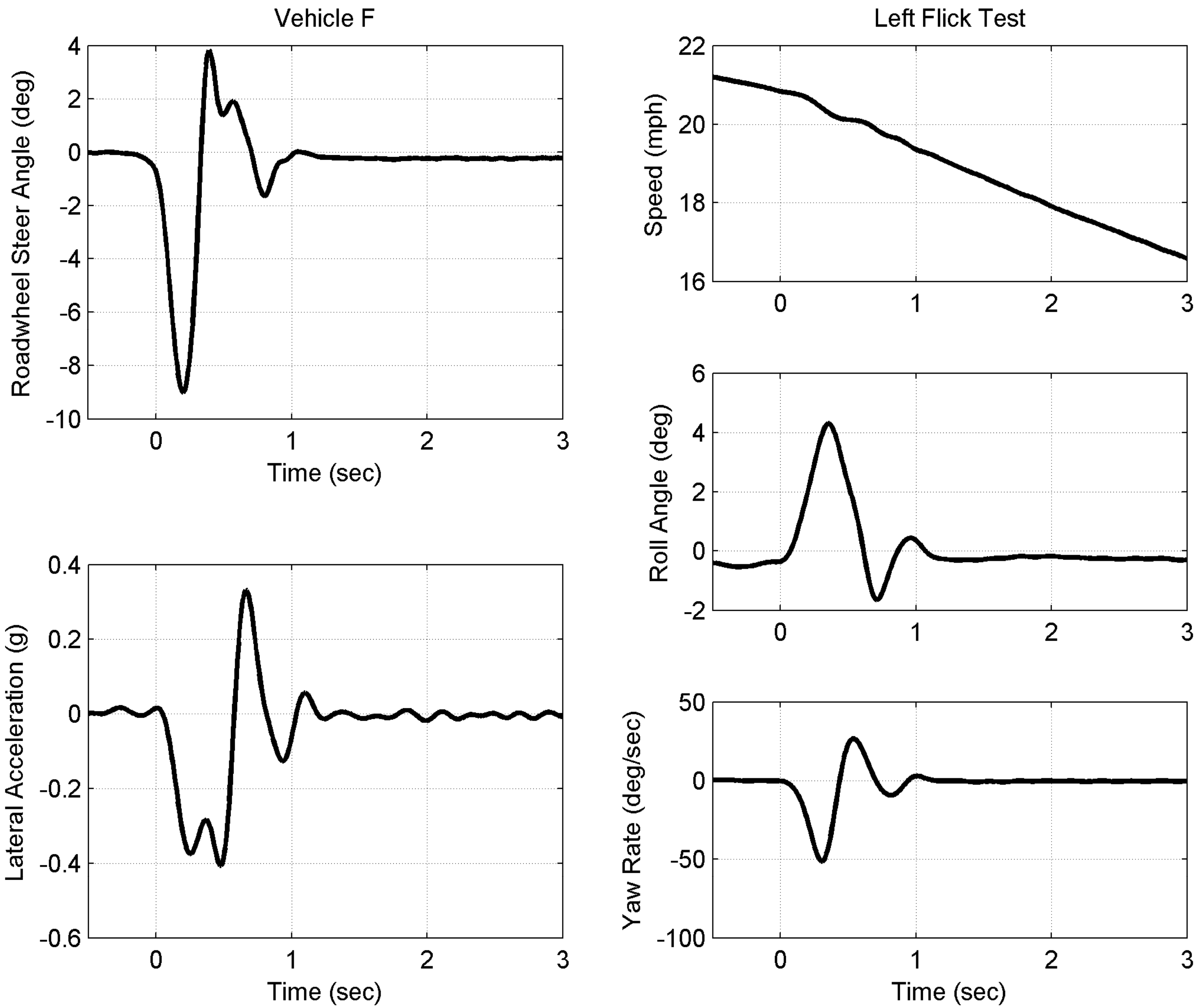
Vehicle F - 25 ft Radius - Constant Steer Test - CW Runs



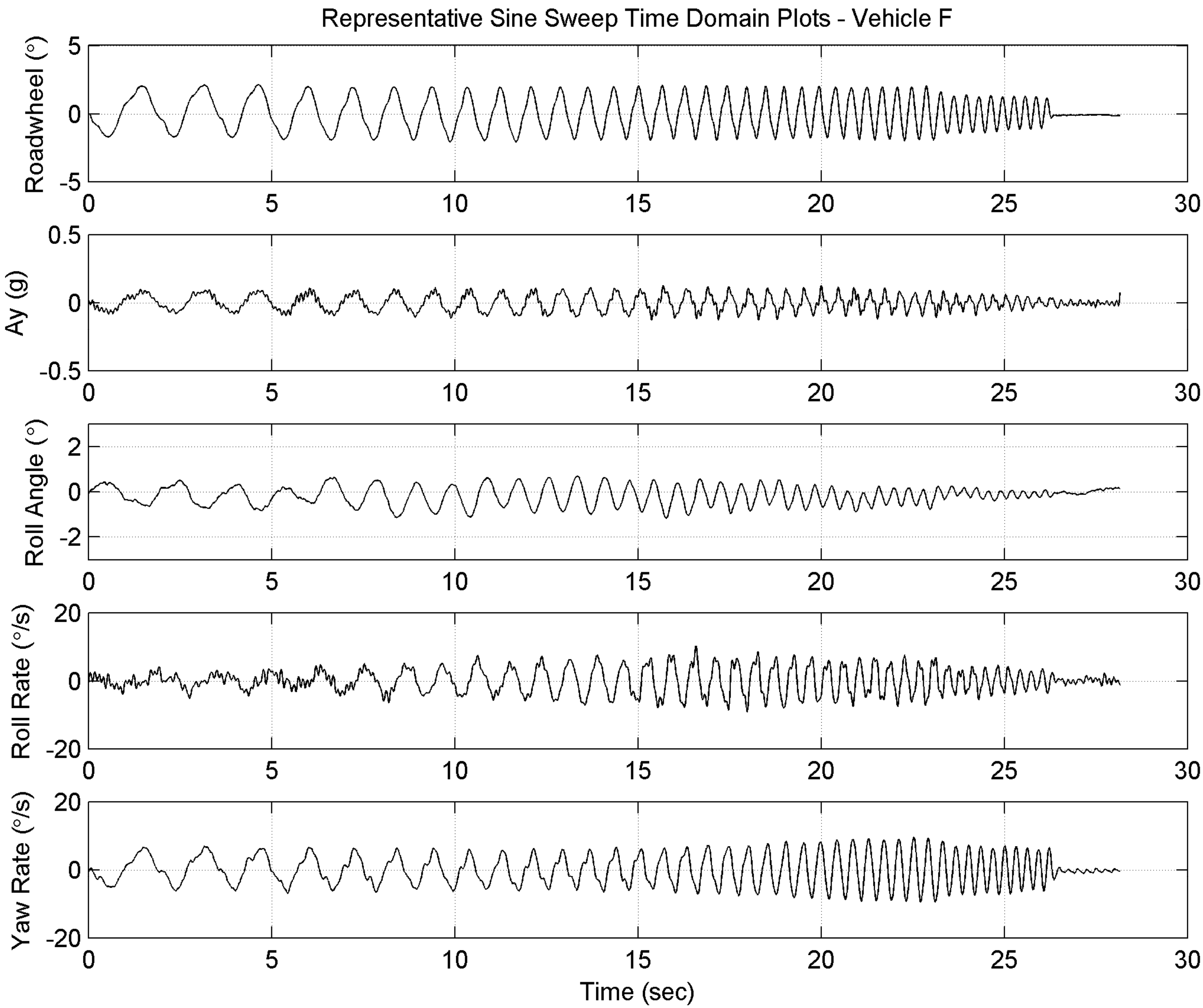


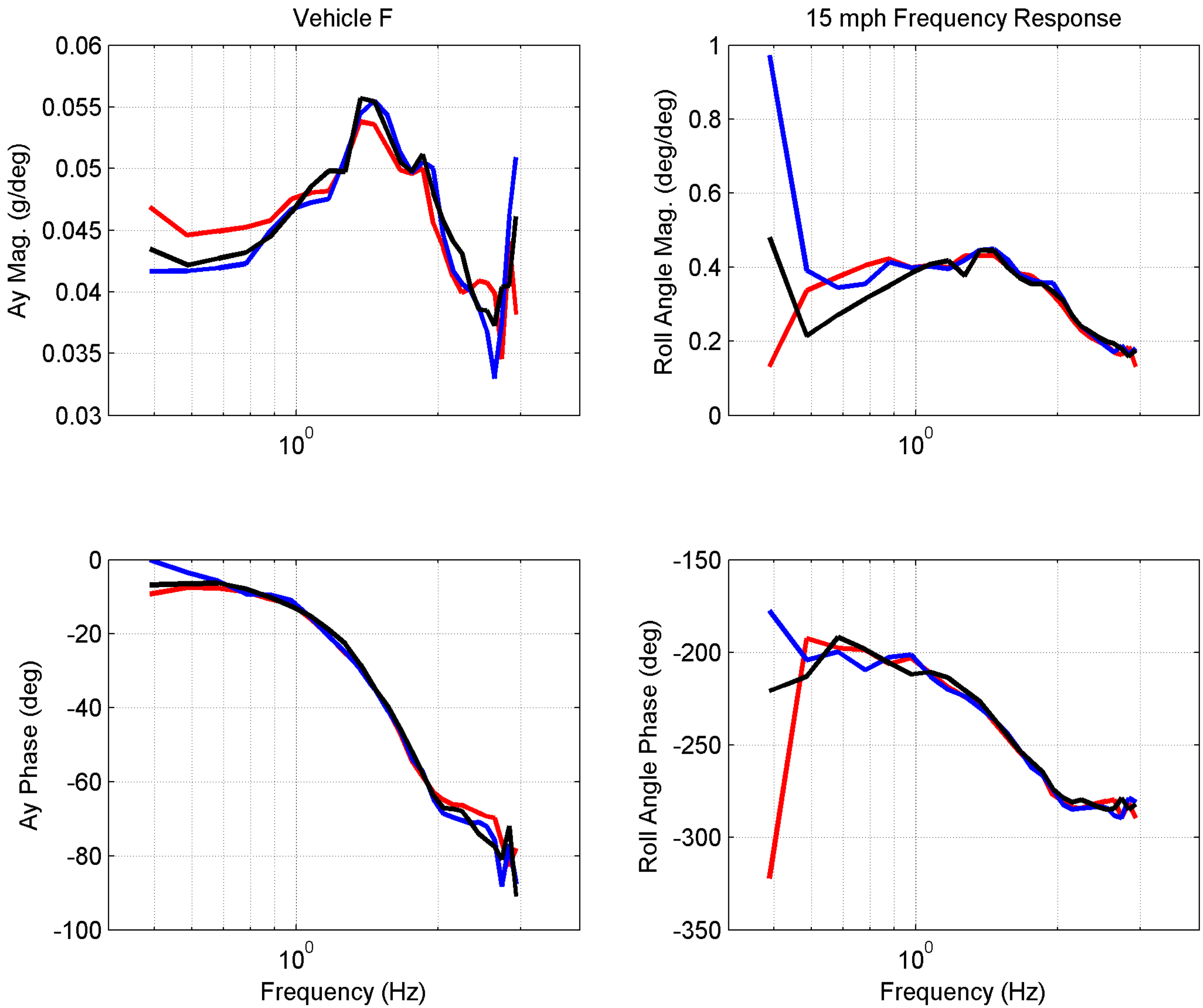
Vehicle F - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.26 g to 0.31 g
Range: 0.31 g to Max g

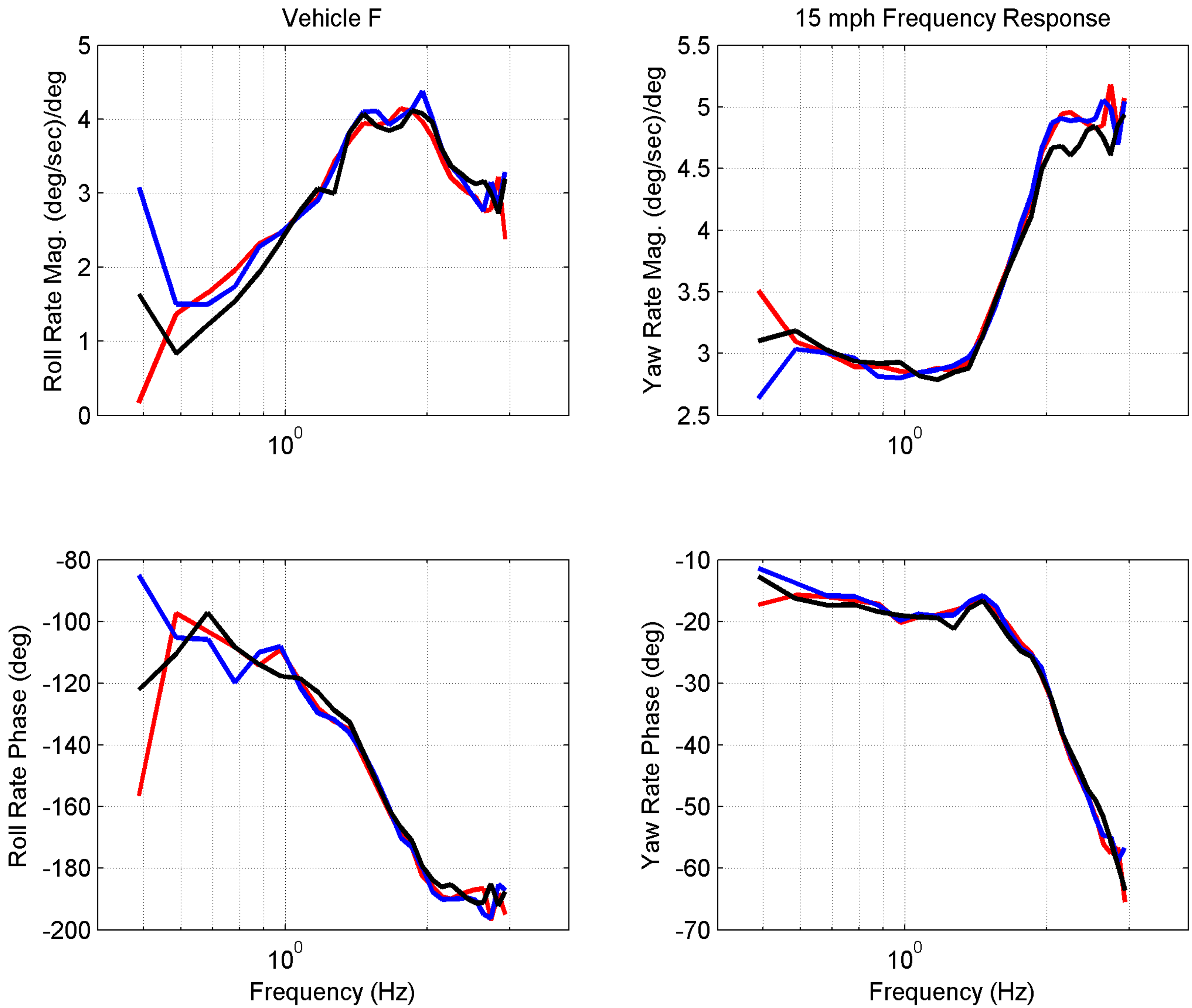

Vehicle F
Right Flick Test
Roadwheel Steer Angle (deg)
8
6
4
2
0
-2
-4
-6
Time (sec)
0
1
2
3
Speed (mph)
22
20
18
16
Roll Angle (deg)
1
0
-1
-2
-3
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
Yaw Rate (deg/sec)
40
20
0
-20

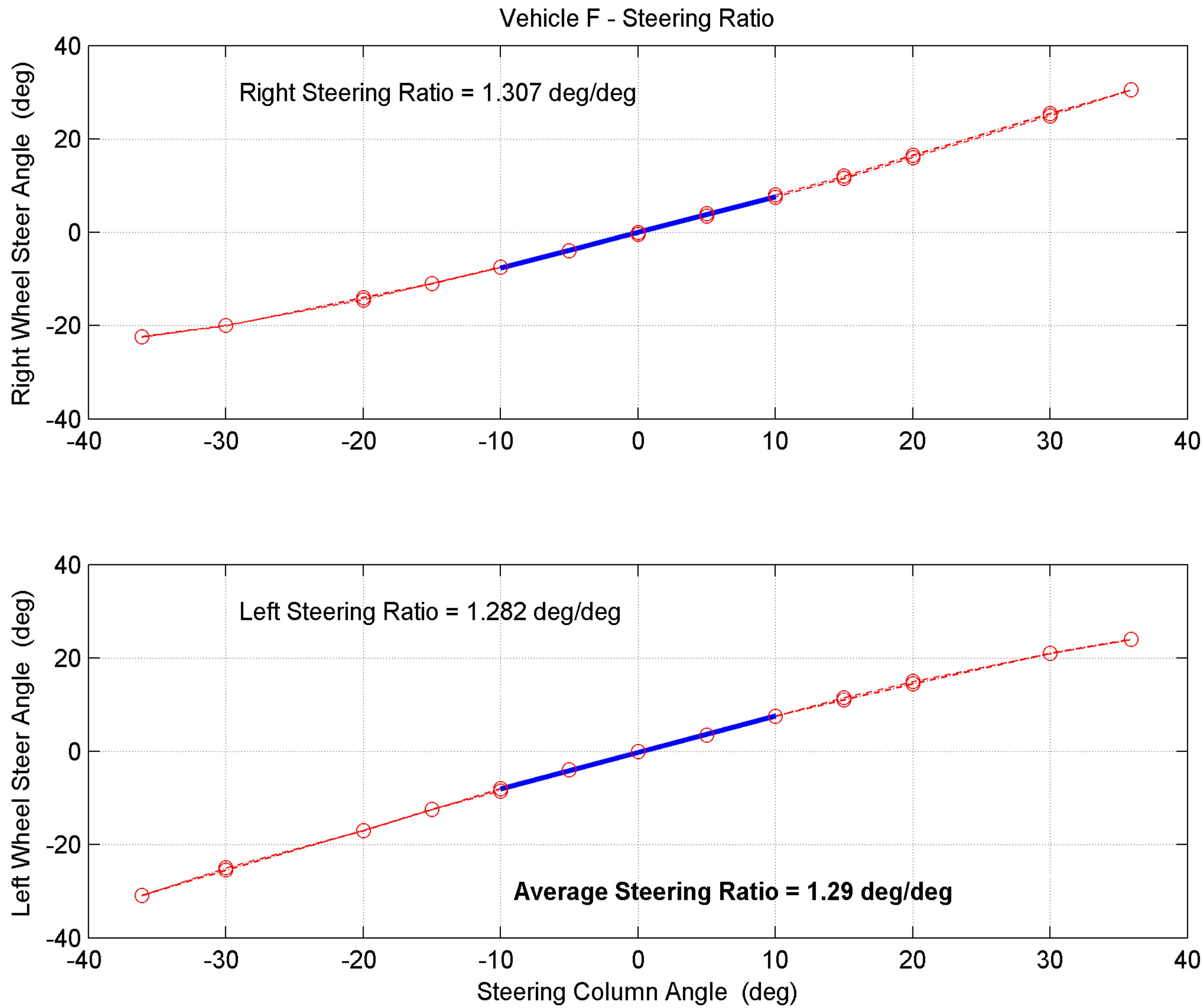


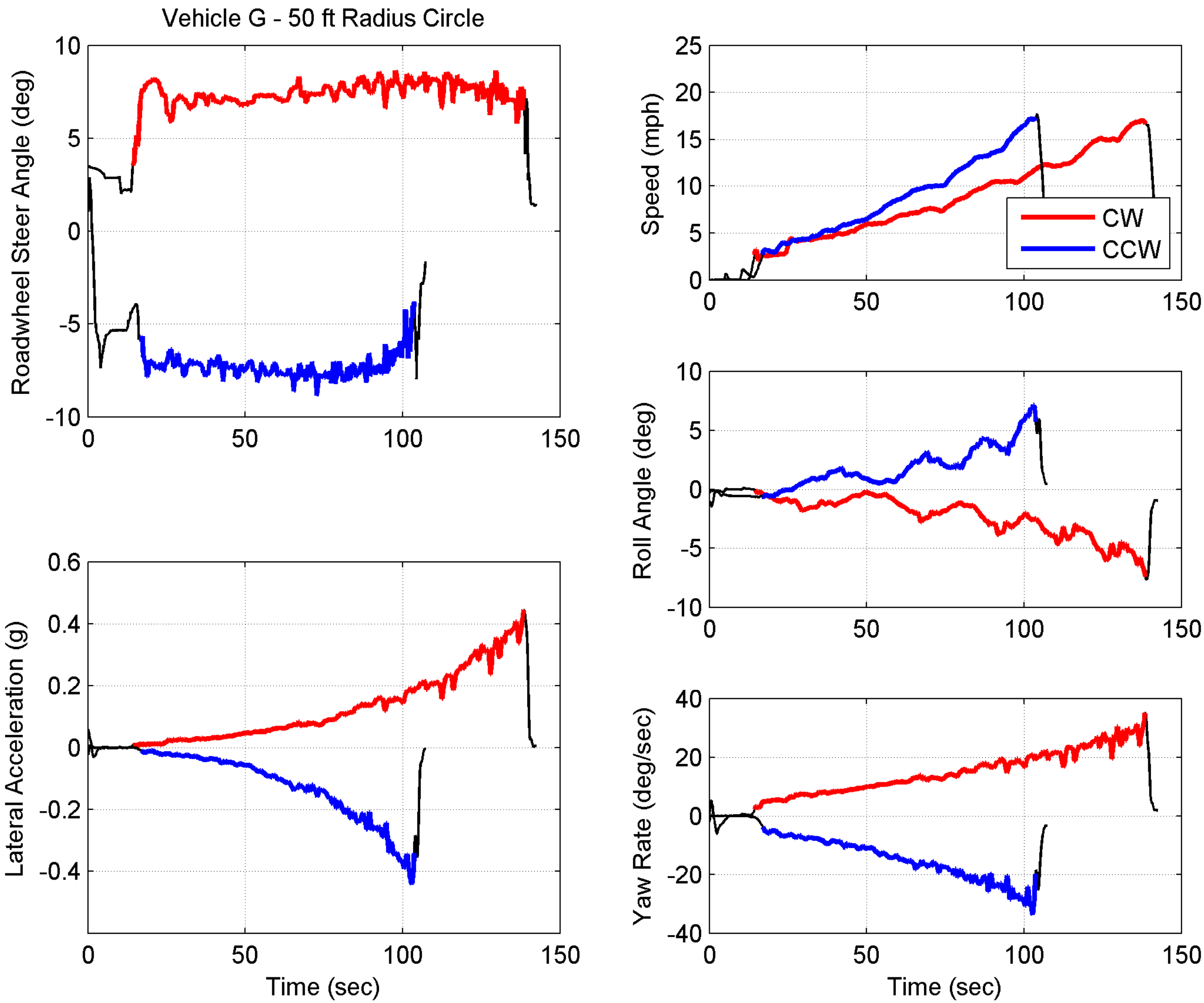
Vehicle F
Left Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

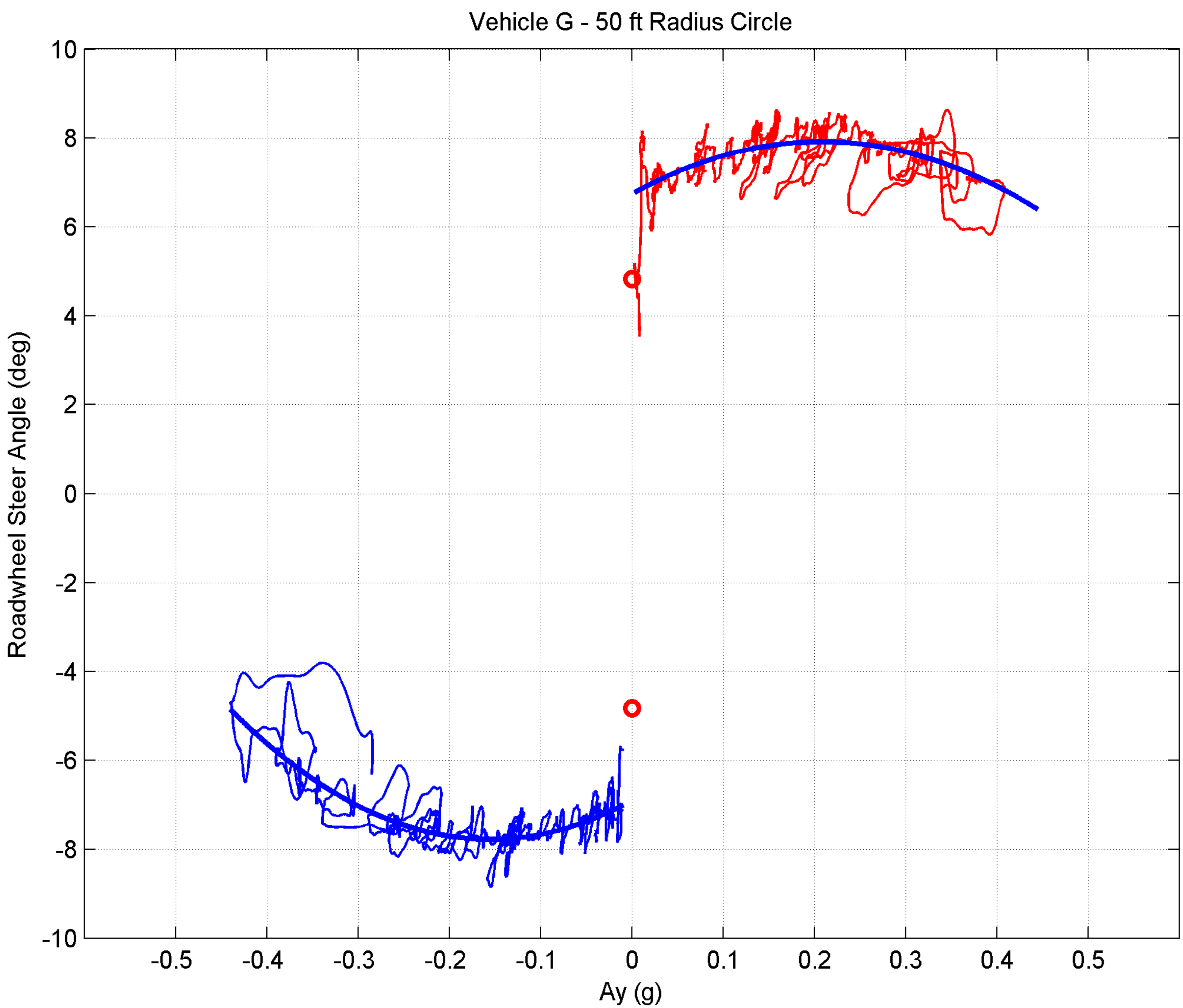

Representative Sine Sweep Time Domain Plots - Vehicle F
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)


Vehicle F
15 mph Frequency Response
Ay Mag. (g/deg)
0.06
0.055
0.05
0.045
0.04
0.035
0.03
10^0
Roll Angle Mag. (deg/deg)
1
0.8
0.6
0.4
0.2
0
10^0
Ay Phase (deg)
0
-20
-40
-60
-80
-100
10^0
Frequency (Hz)
Roll Angle Phase (deg)
-150
-200
-250
-300
-350
10^0
Frequency (Hz)

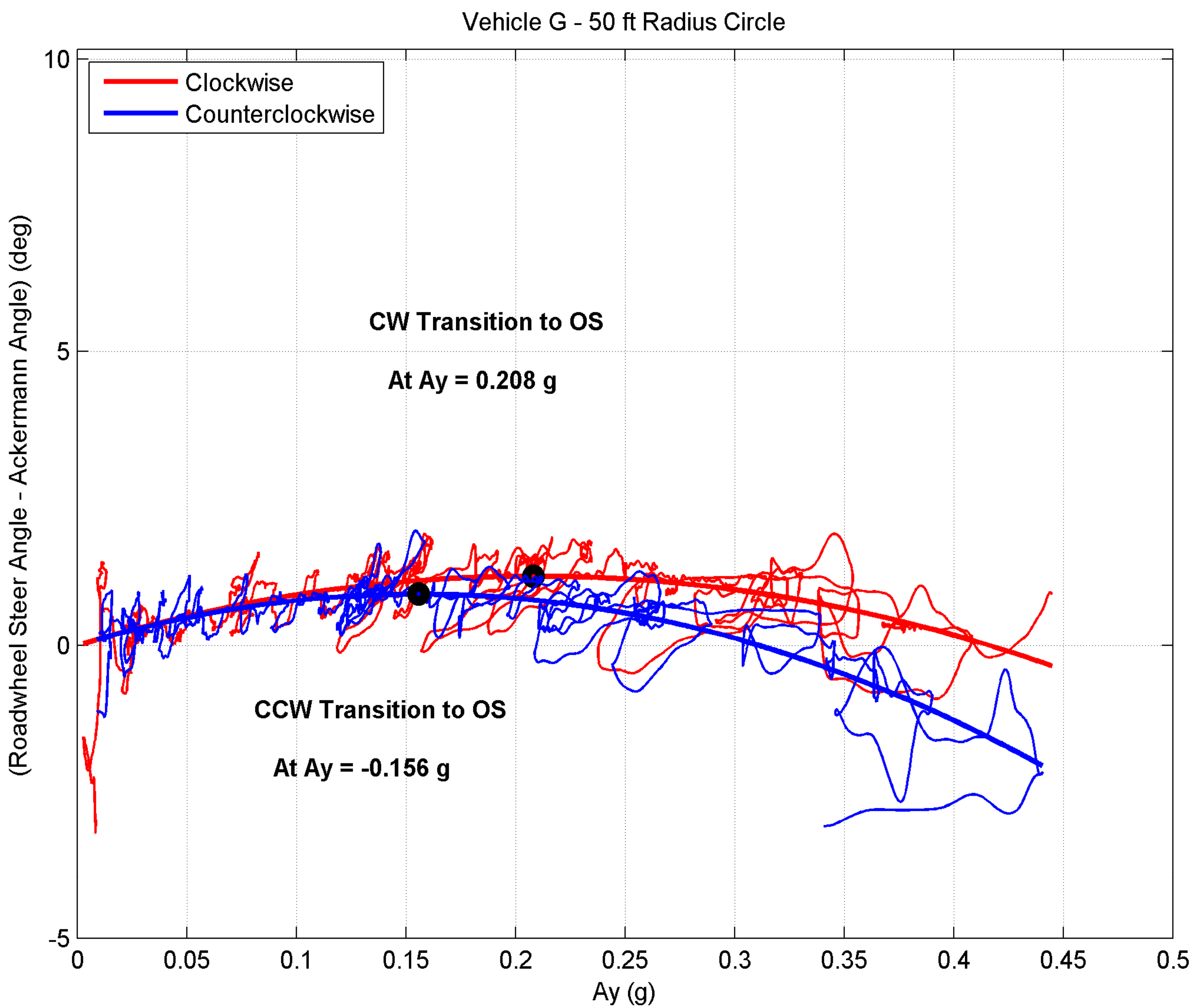

Vehicle F
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)


Vehicle F - Steering Ratio
Right Steering Ratio = 1.307 deg/deg
Right Wheel Steer Angle (deg)
Left Steering Ratio = 1.282 deg/deg
Left Wheel Steer Angle (deg)
Average Steering Ratio = 1.29 deg/deg
Steering Column Angle (deg)
40
20
0
-20
-40
-40
-30
-20
-10
0
10
20
30
40

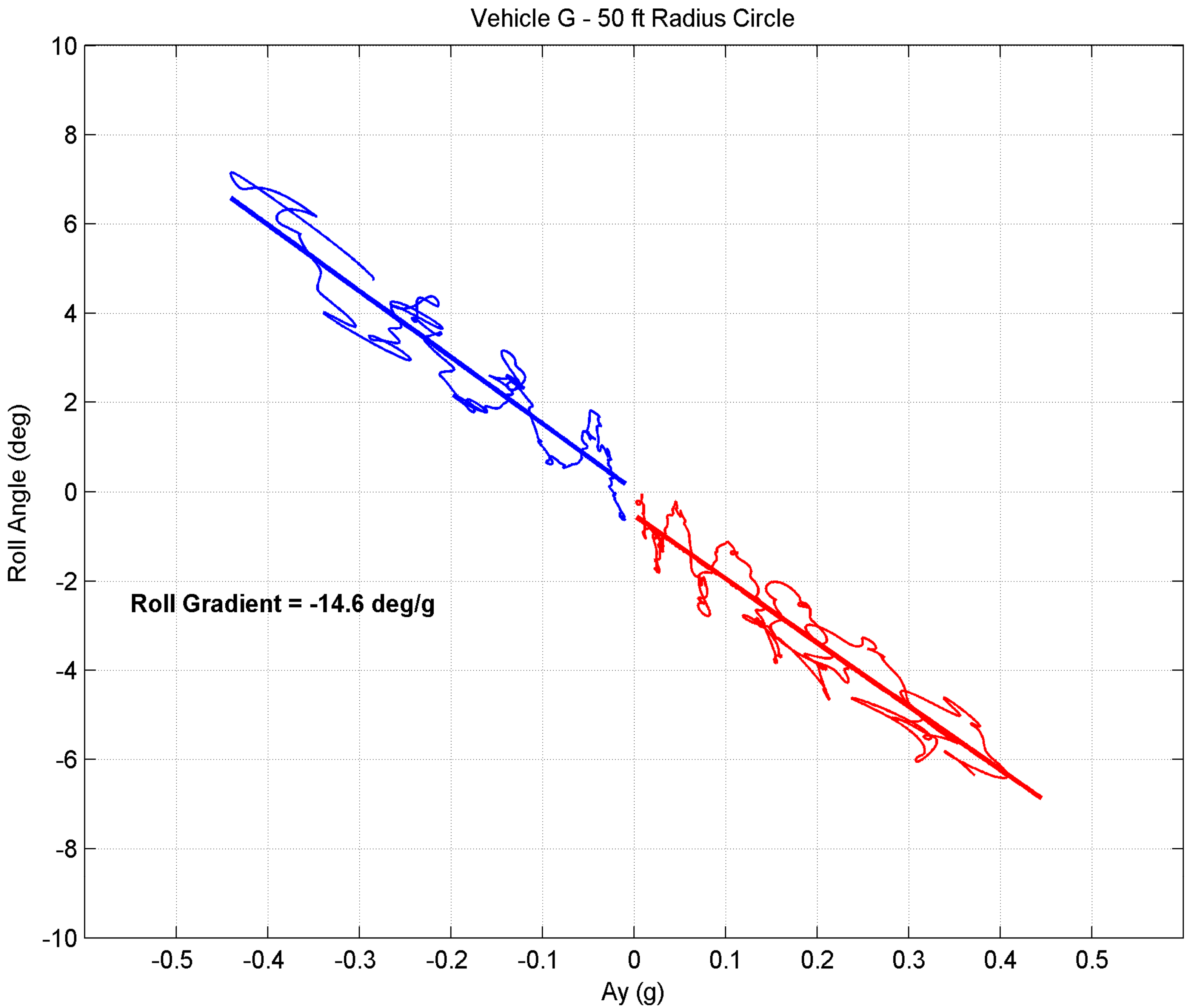

Vehicle G - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

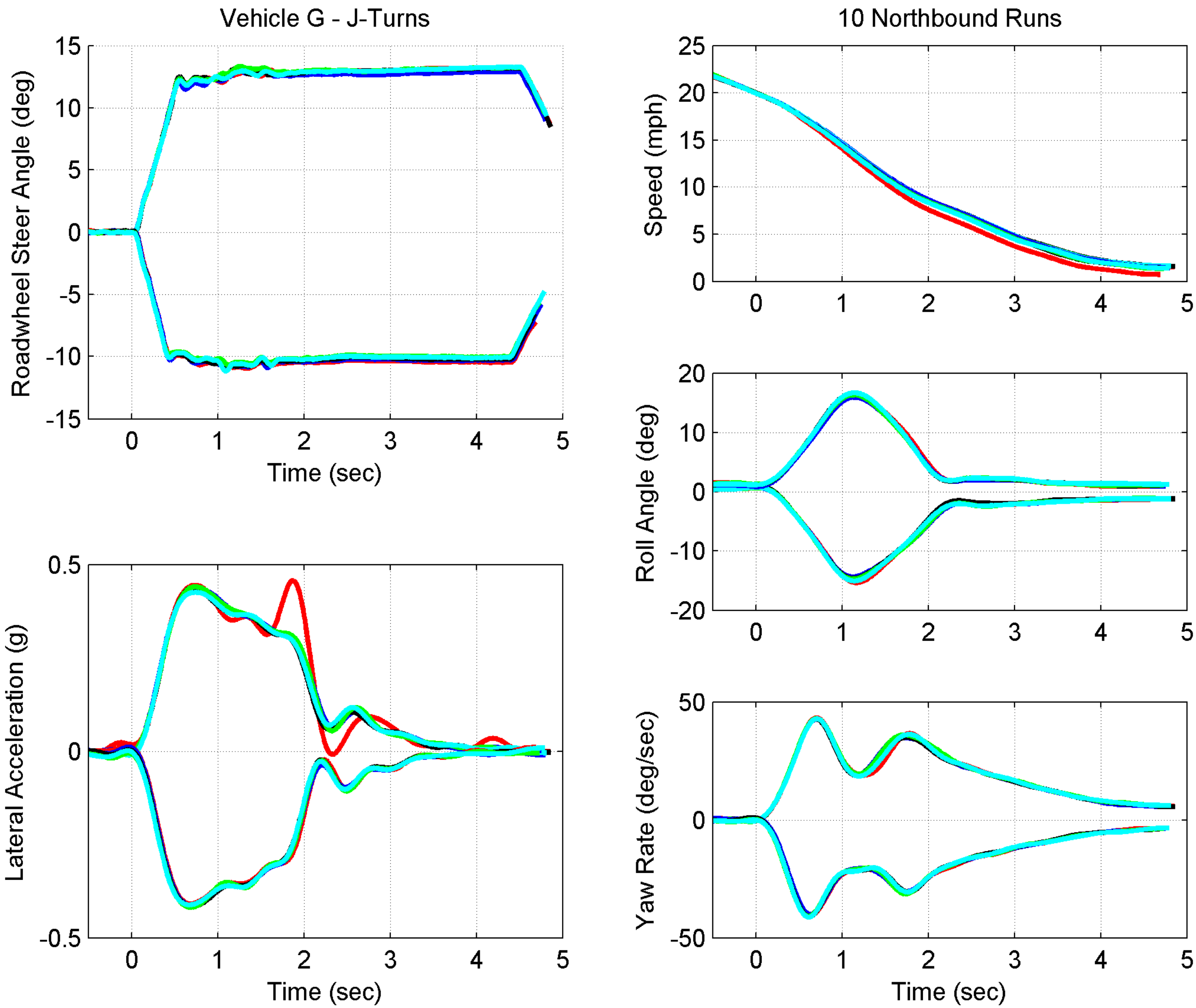


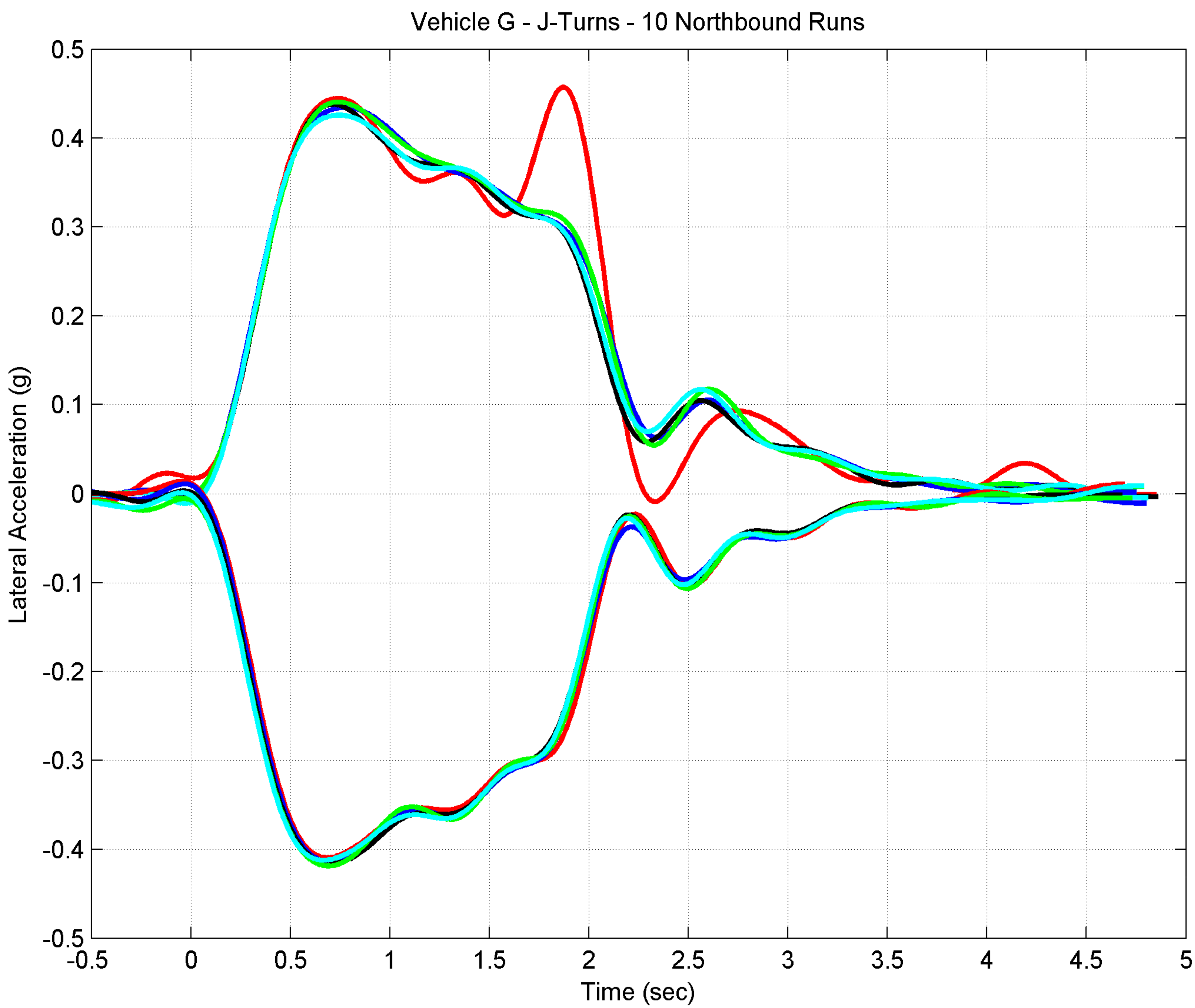
Vehicle G - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5



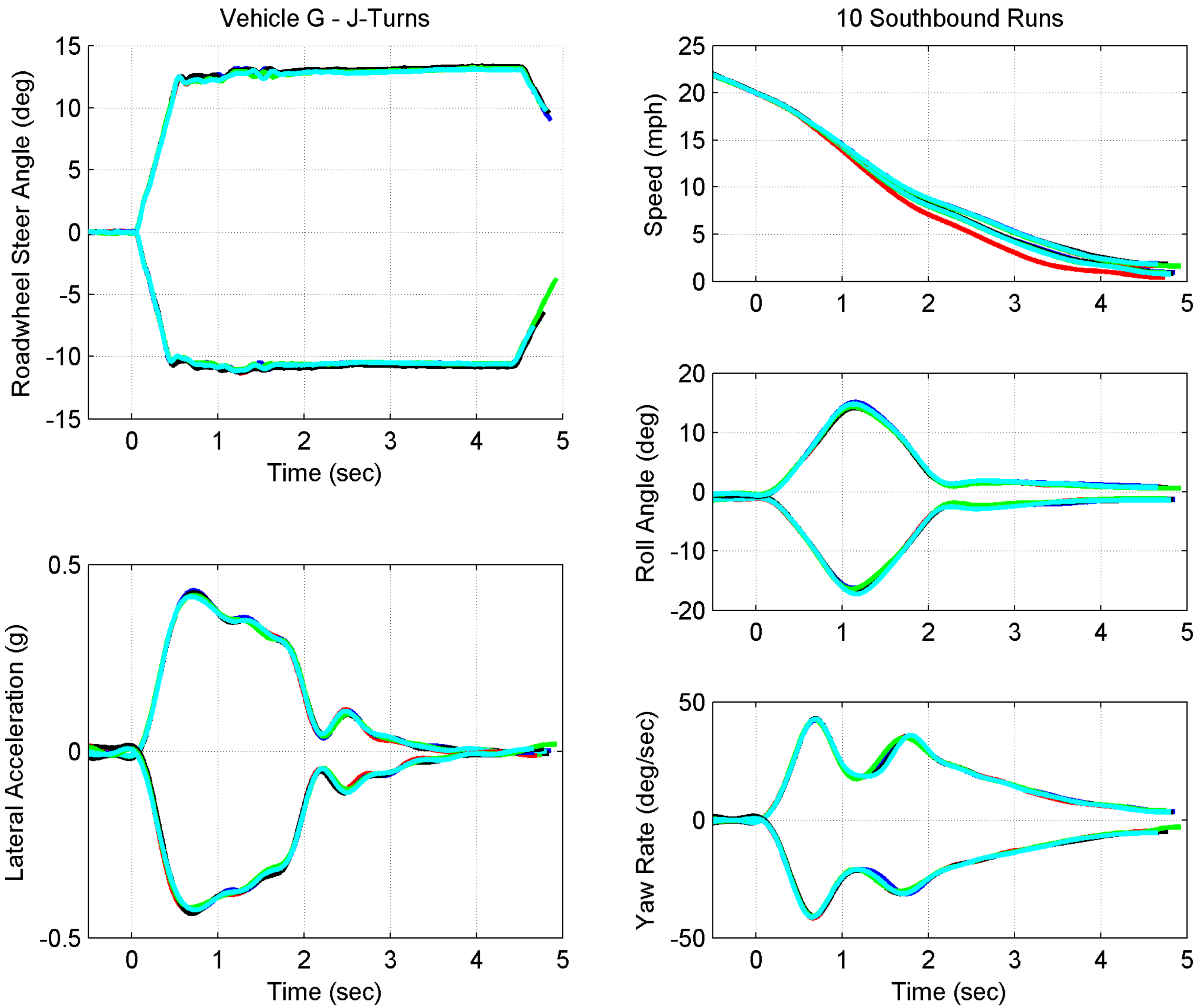
Vehicle G - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.208 g
CCW Transition to OS
At Ay = -0.156 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5


Vehicle G - 50 ft Radius Circle
Roll Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
Roll Gradient = -14.6 deg/g
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

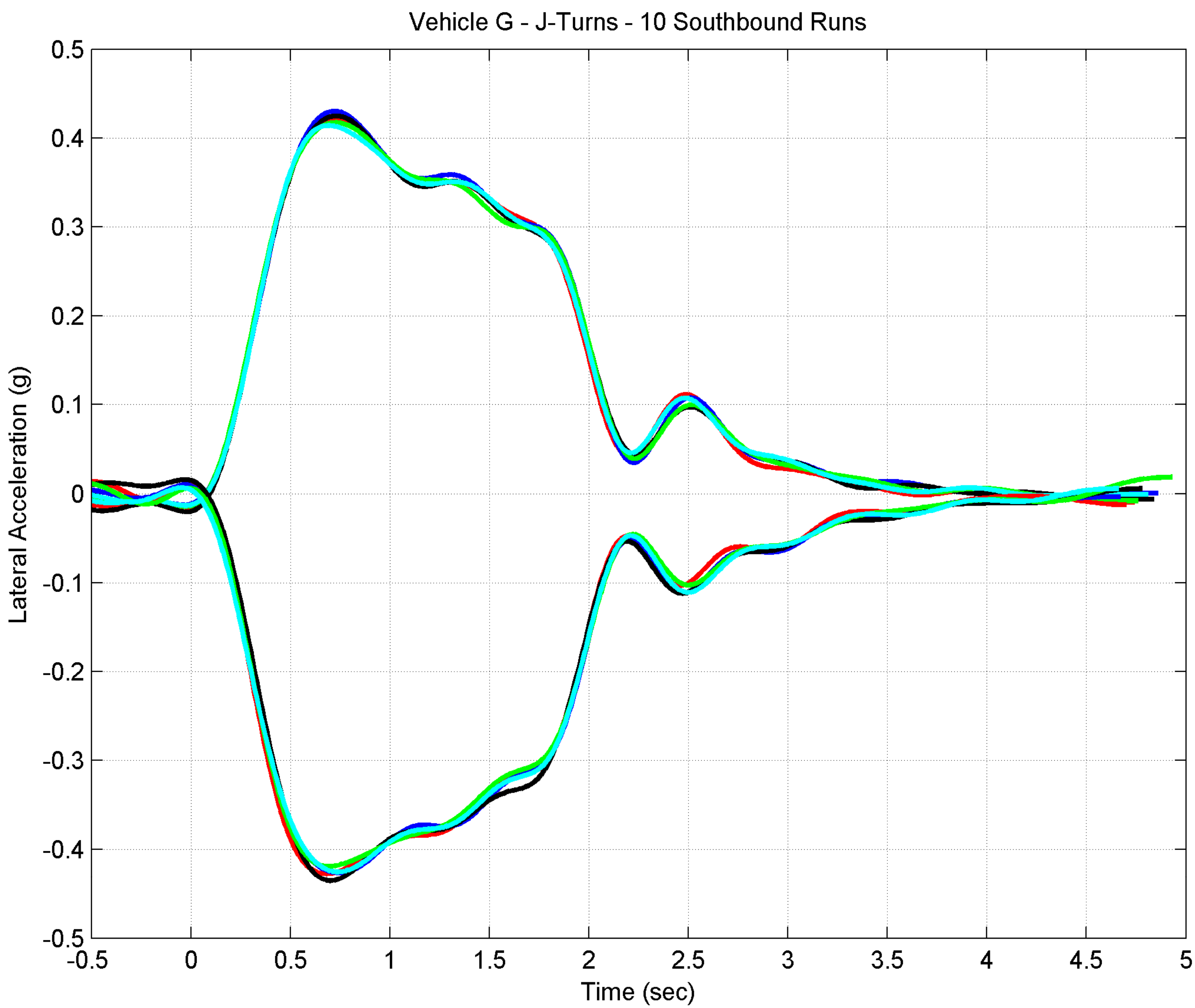

Vehicle G - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)



Vehicle G - J-Turns - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle G - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle G - J-Turns - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle G

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

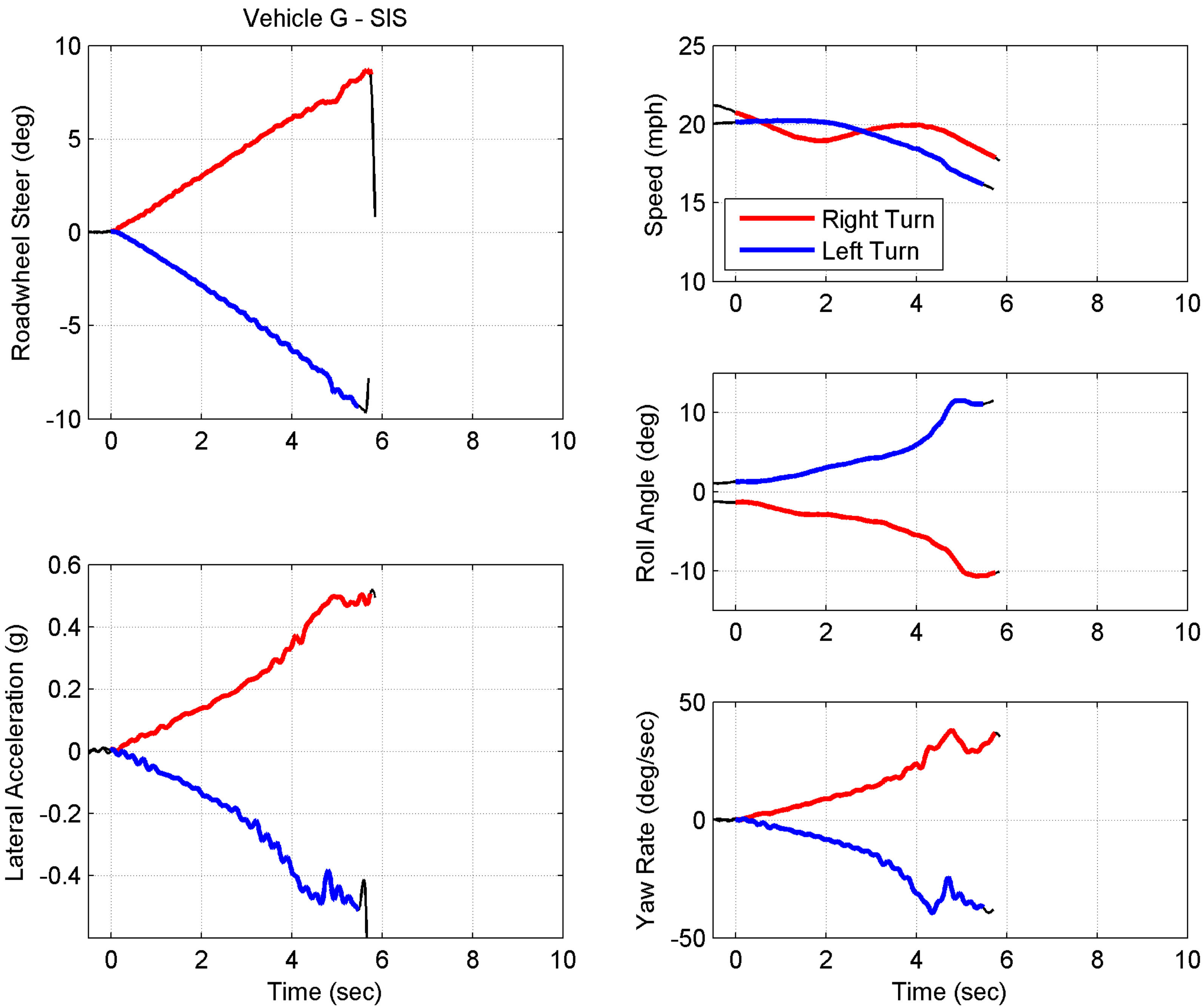
Run Number	Northbound Right Turns	Northbound Left Turns	Average of 10 Northbound Runs
1	0.4572	-0.4094	
2	0.4344	-0.4145	
3	0.4381	-0.4157	
4	0.4407	-0.4188	
5	0.4259	-0.4123	
Mean Value of 5 Runs	0.4393	-0.4141	**0.4267**
Standard Deviation of 5 Runs	0.011	0.004	

Run Number	Southbound Right Turns	Southbound Left Turns	Average of 10 Southbound Runs
1	0.4208	-0.4275	
2	0.4303	-0.4263	
3	0.4250	-0.4356	
4	0.4175	-0.4192	
5	0.4142	-0.4254	
Mean Value of 5 Runs	0.4216	-0.4268	**0.4242**
Standard Deviation of 5 Runs	0.006	0.006	

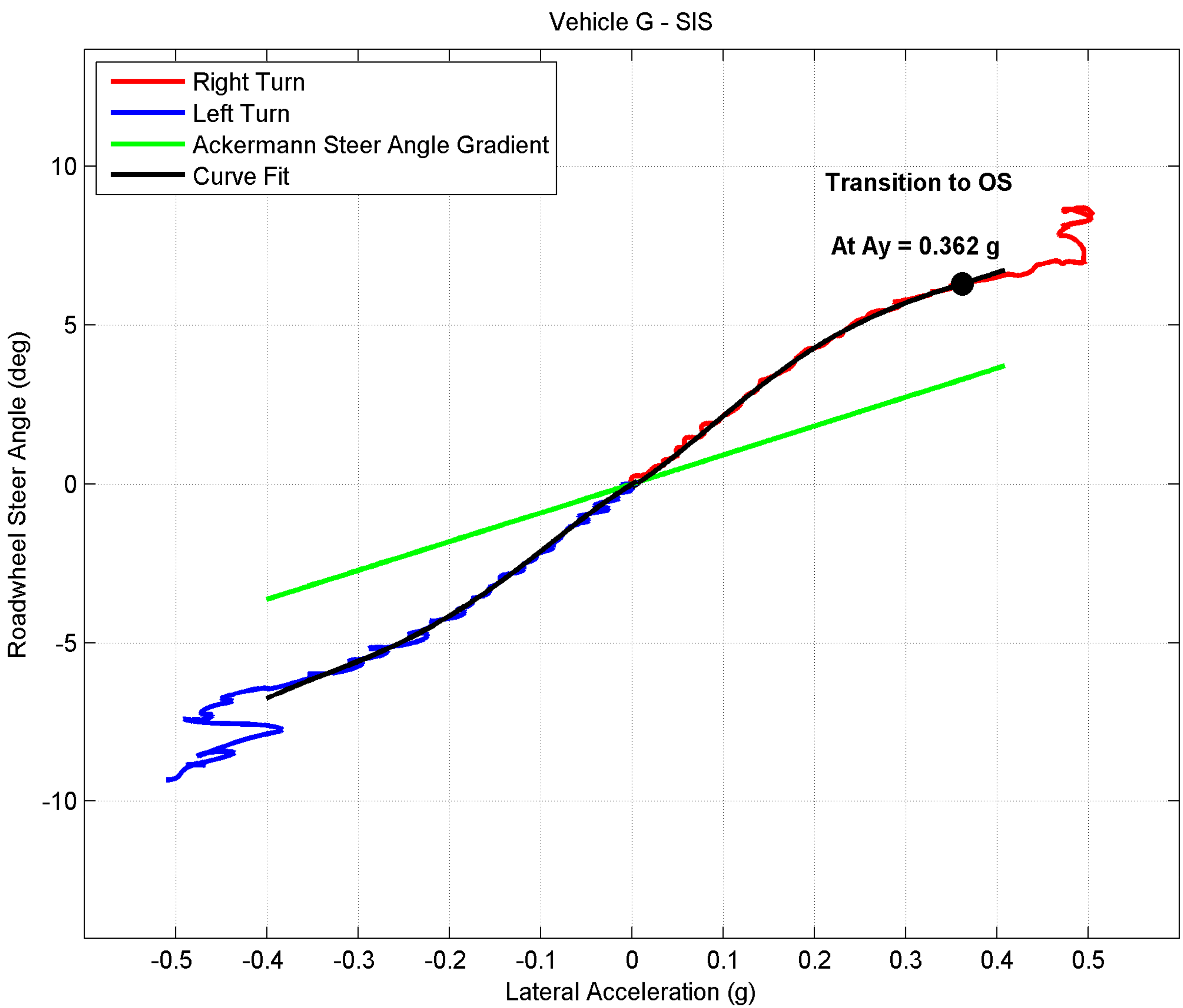
Average of All 20 Runs

0.425

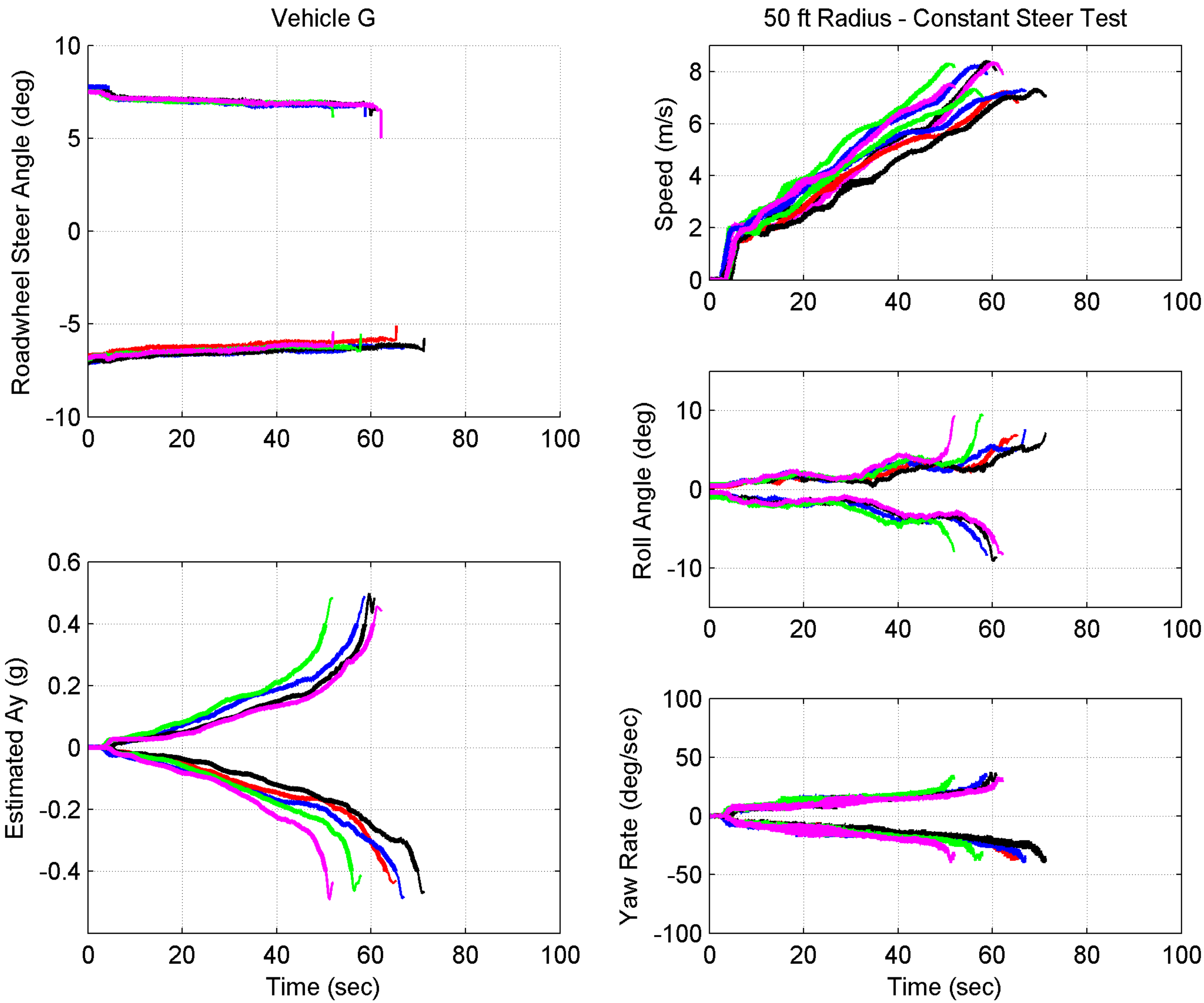
Threshold Ay



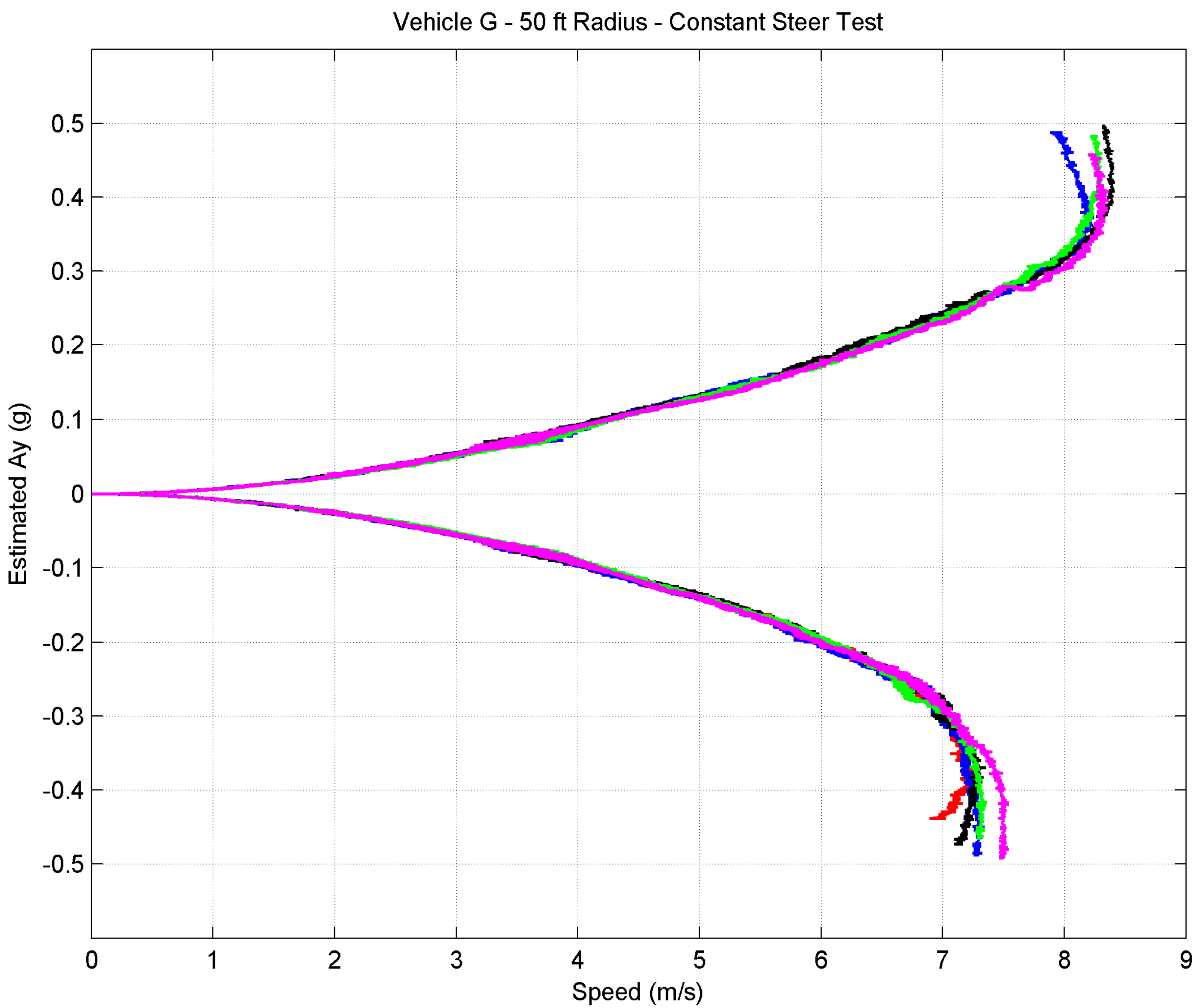
Vehicle G - SIS
Roadwheel Steer (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

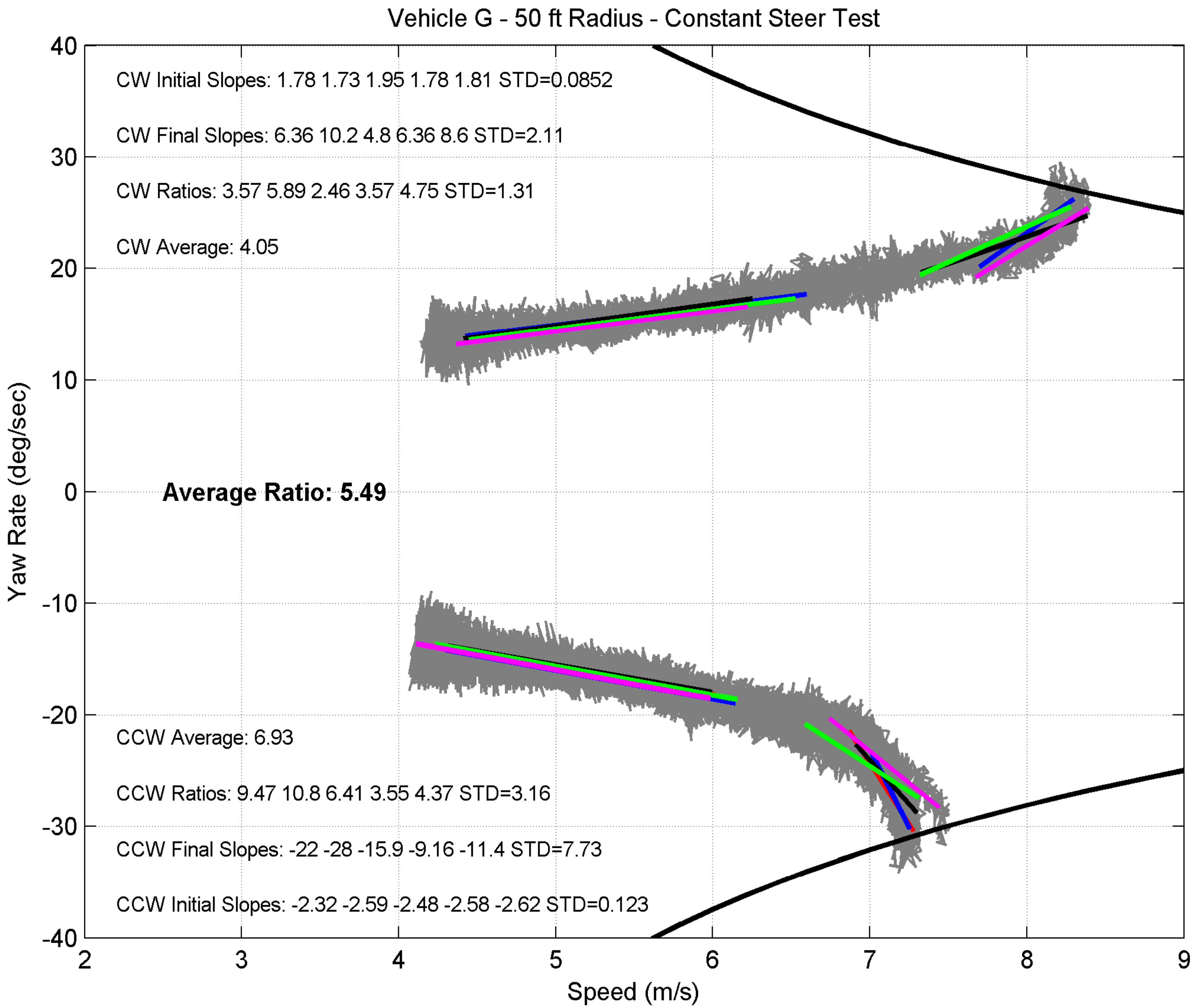


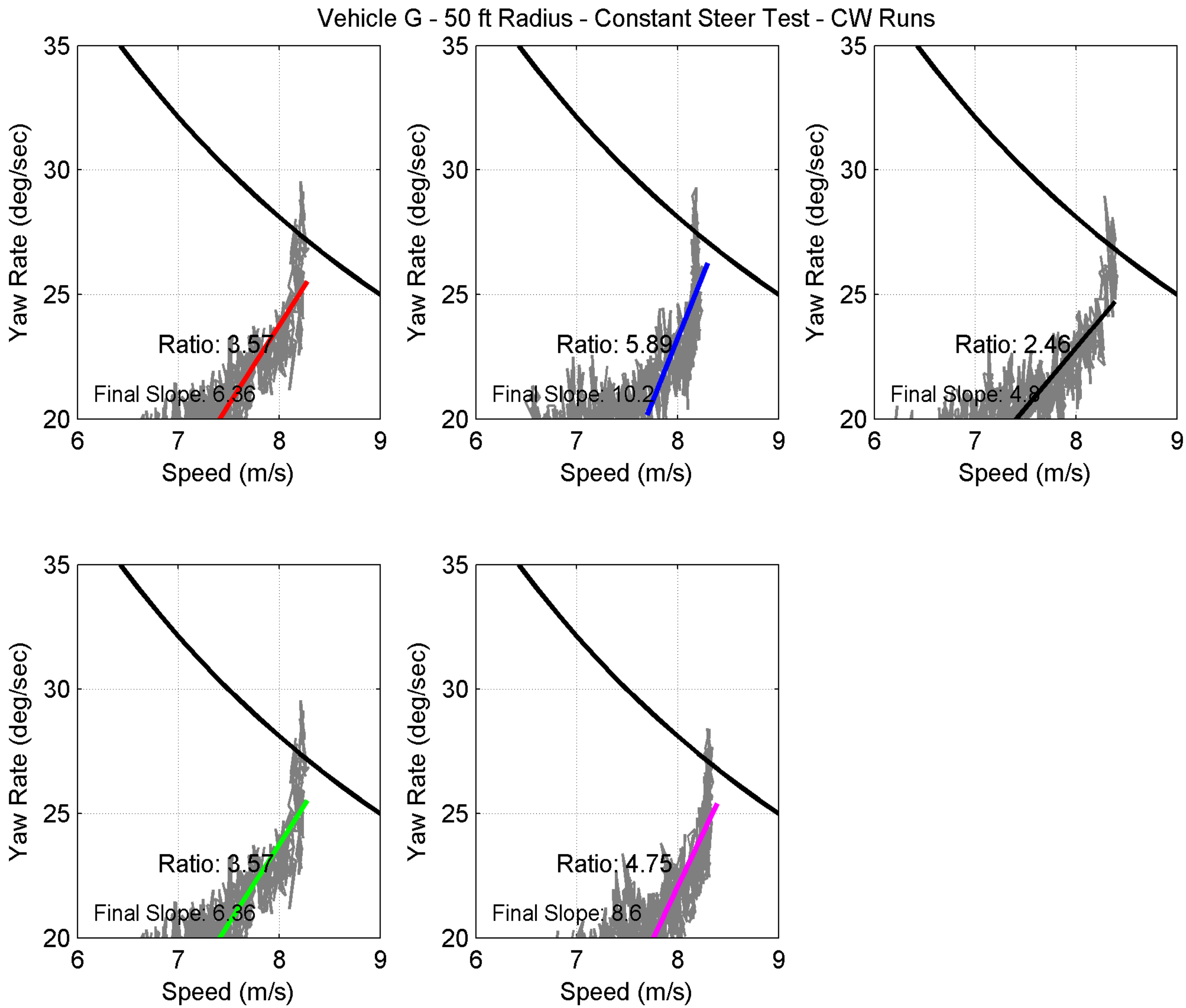
Vehicle G - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to OS
At Ay = 0.362 g
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
10
5
0
-5
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

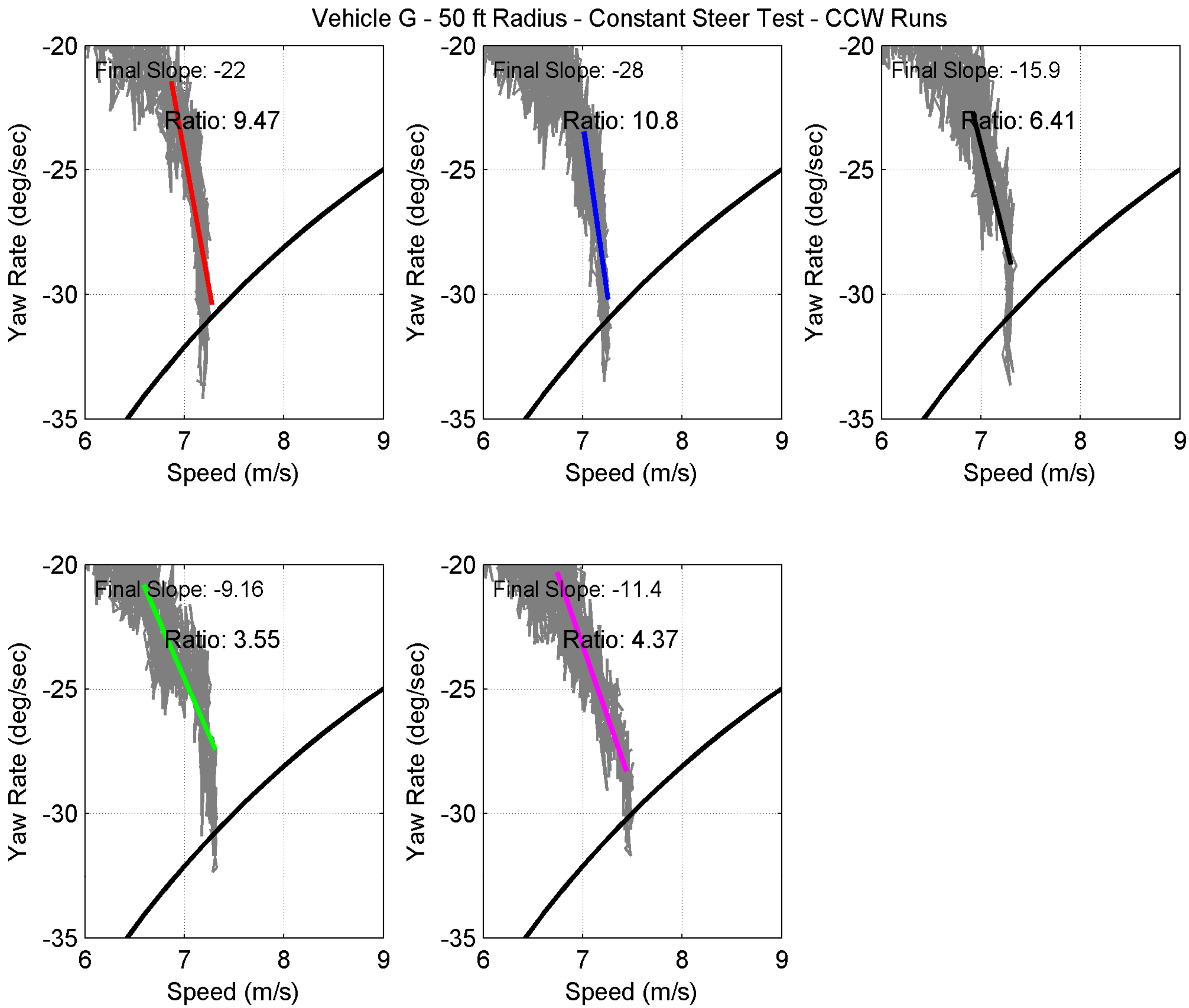


Vehicle G
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

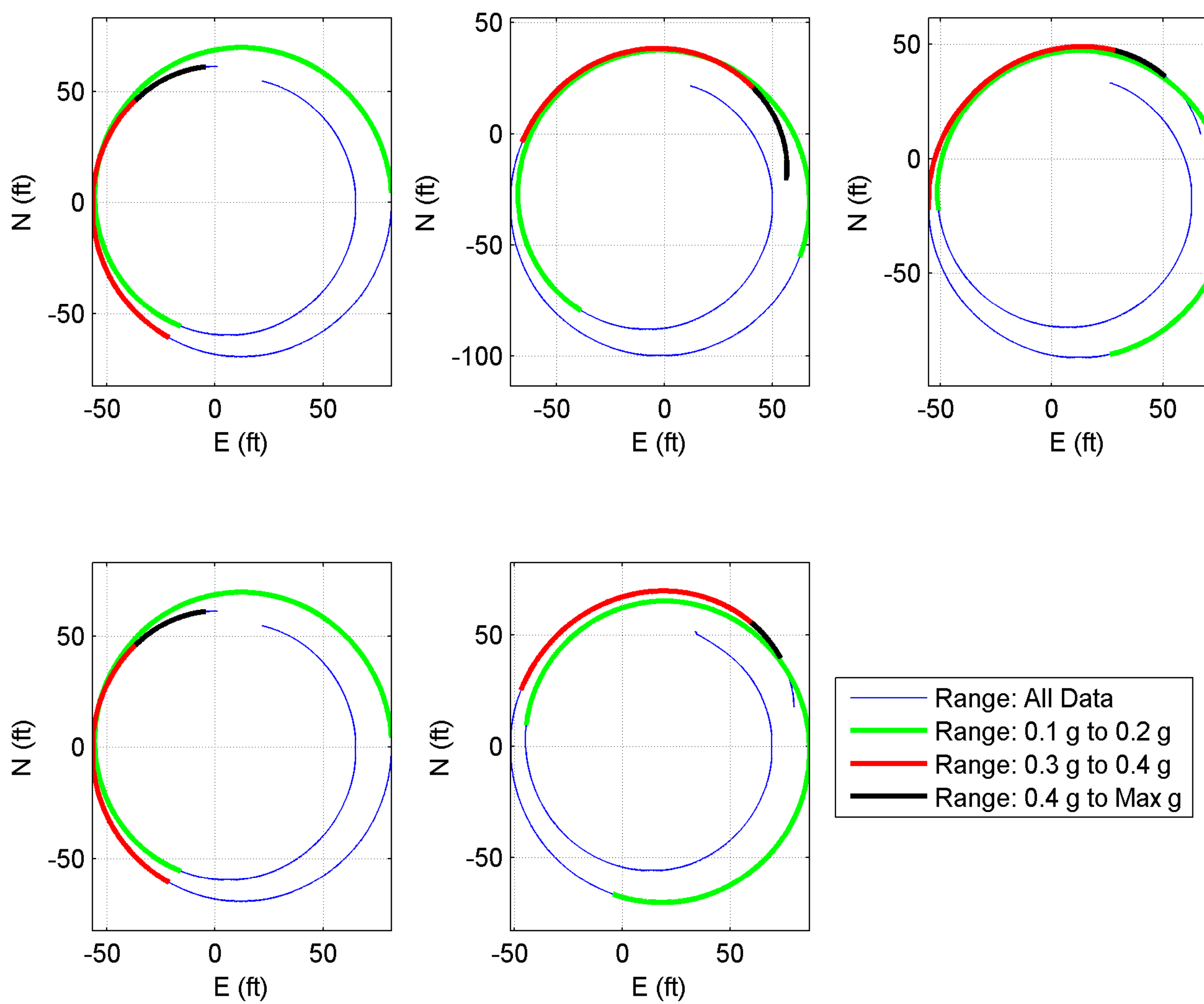

Vehicle G - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

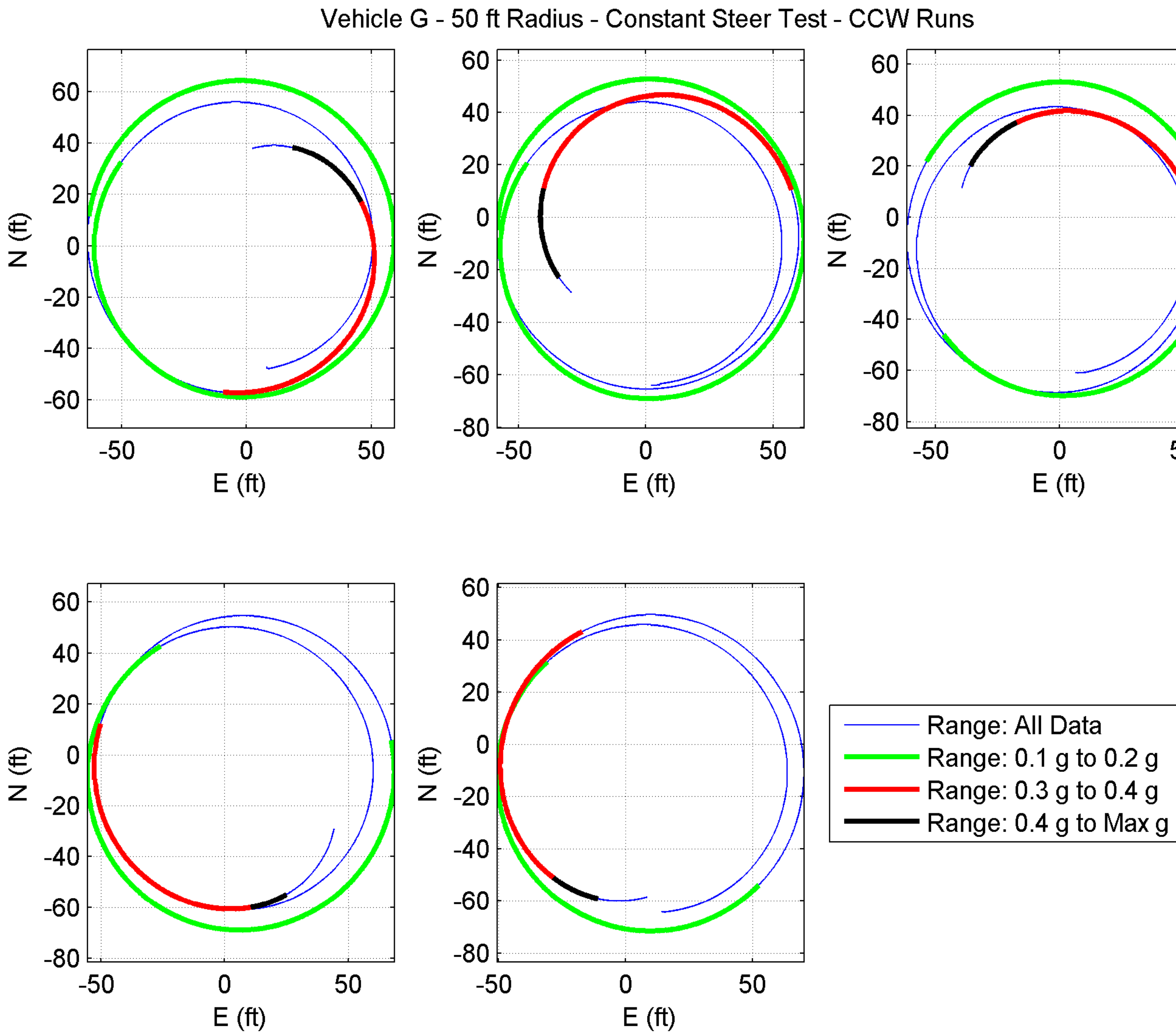

Vehicle G - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 1.78 1.73 1.95 1.78 1.81 STD=0.0852
CW Final Slopes: 6.36 10.2 4.8 6.36 8.6 STD=2.11
CW Ratios: 3.57 5.89 2.46 3.57 4.75 STD=1.31
CW Average: 4.05
Average Ratio: 5.49
CCW Average: 6.93
CCW Ratios: 9.47 10.8 6.41 3.55 4.37 STD=3.16
CCW Final Slopes: -22 -28 -15.9 -9.16 -11.4 STD=7.73
CCW Initial Slopes: -2.32 -2.59 -2.48 -2.58 -2.62 STD=0.123
Yaw Rate (deg/sec)
Speed (m/s)
40
30
20
10
0
-10
-20
-30
-40
2
3
4
5
6
7
8
9


Vehicle G - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 3.57
Final Slope: 6.36
Ratio: 5.89
Final Slope: 10.2
Ratio: 2.46
Final Slope: 4.8
Ratio: 3.57
Final Slope: 6.36
Ratio: 4.75
Final Slope: 8.6

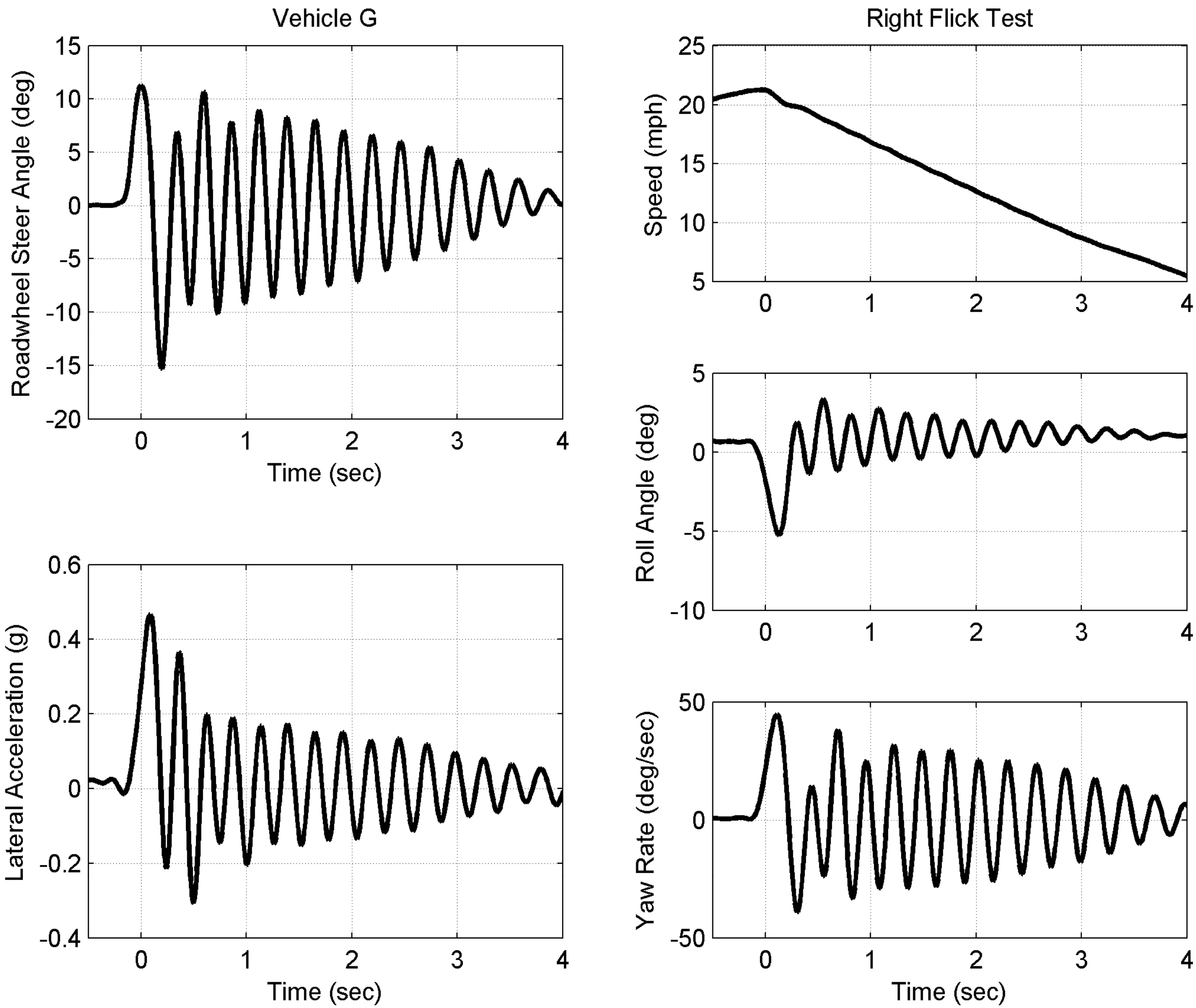

Vehicle G - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -22
Ratio: 9.47
Final Slope: -28
Ratio: 10.8
Final Slope: -15.9
Ratio: 6.41
Final Slope: -9.16
Ratio: 3.55
Final Slope: -11.4
Ratio: 4.37
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

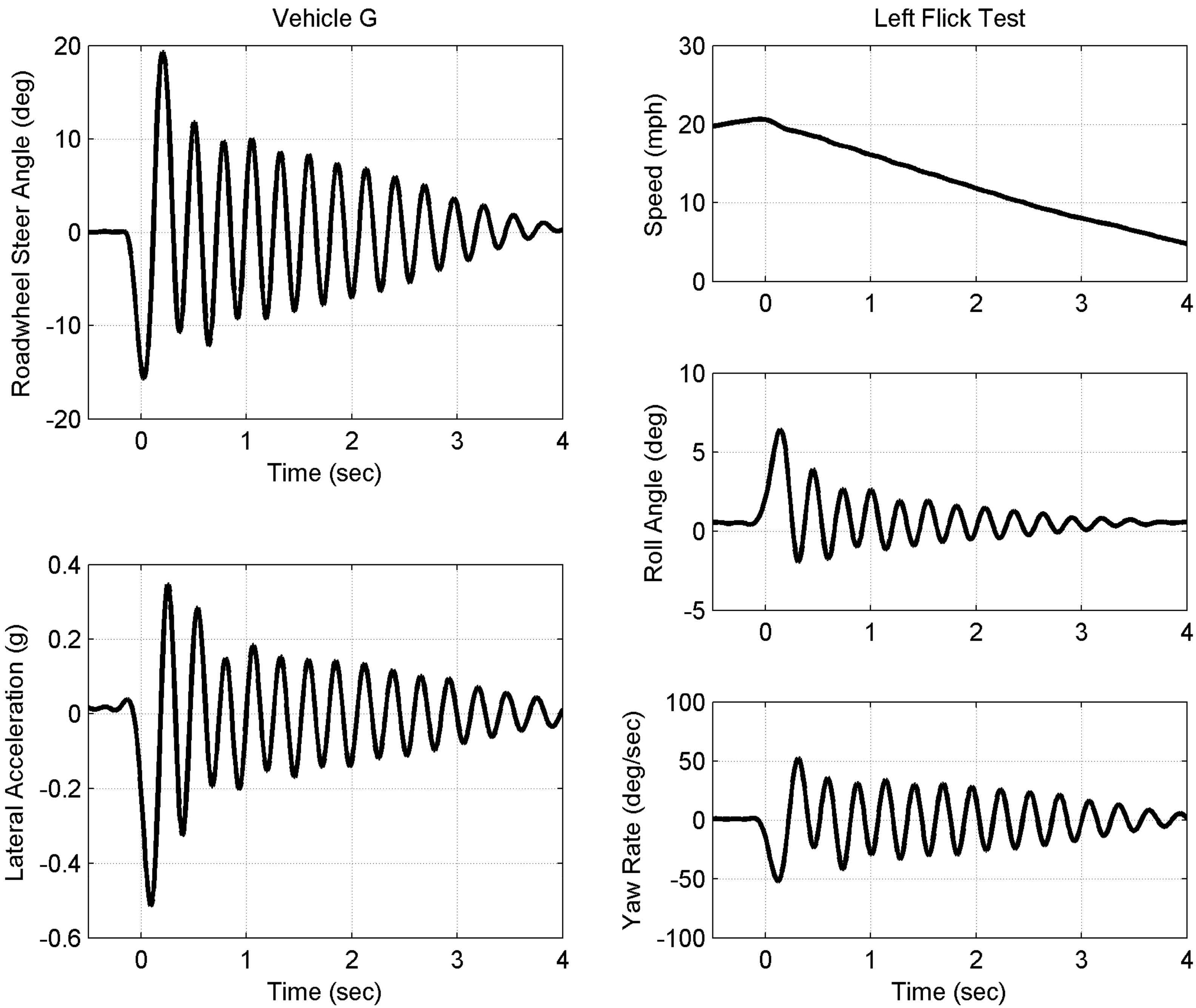
Vehicle G - 50 ft Radius - Constant Steer Test - CW Runs

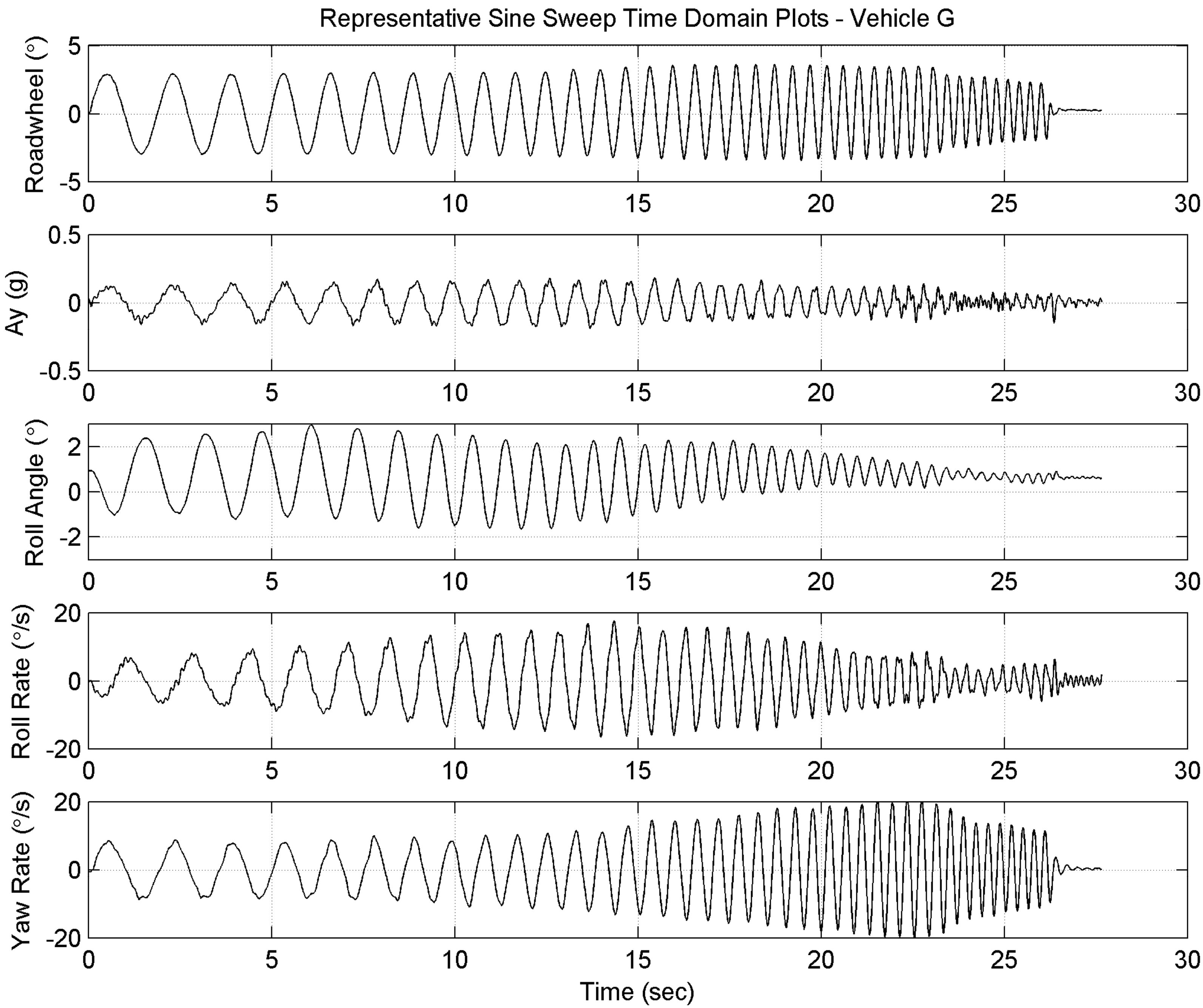


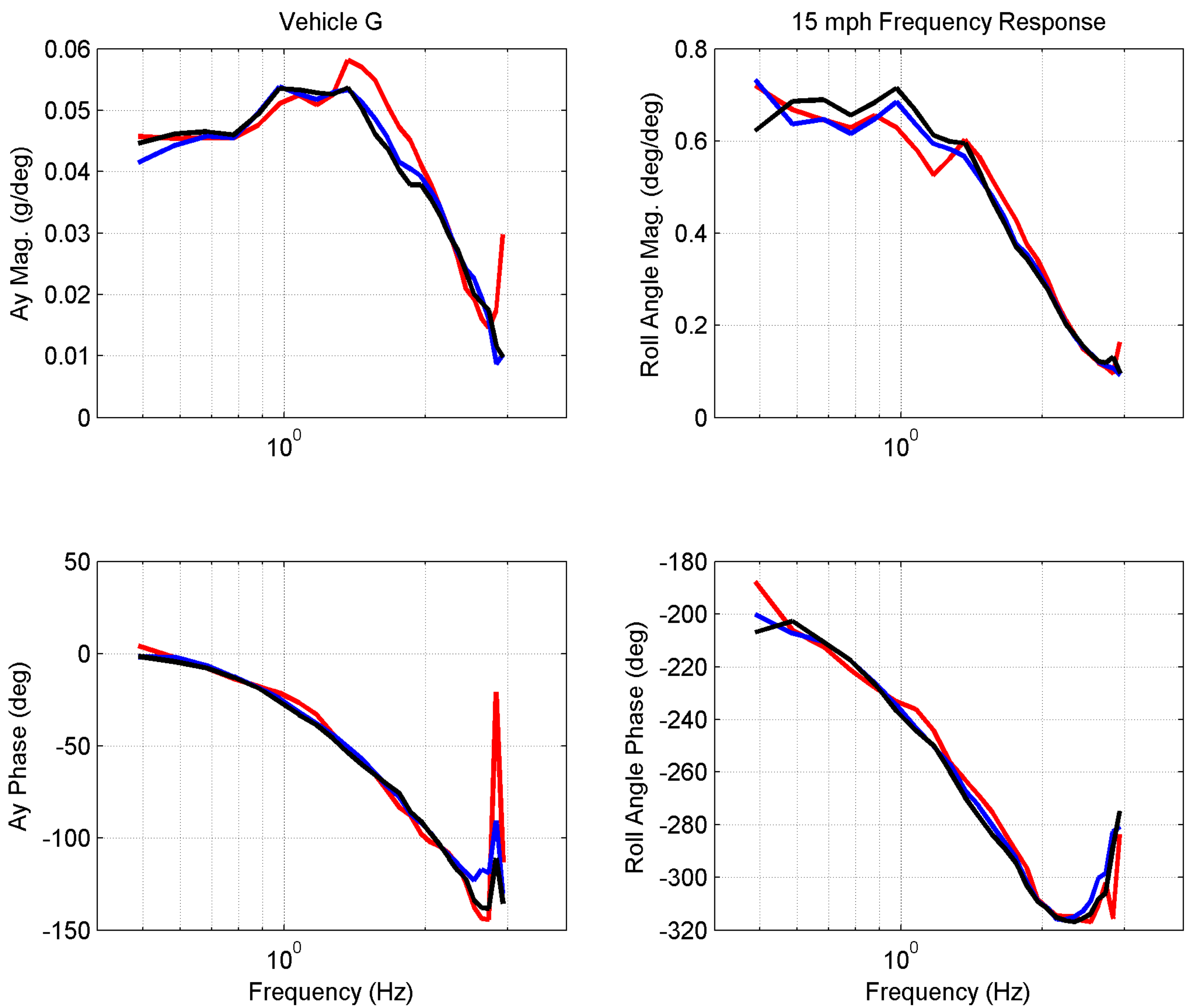


Vehicle G - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

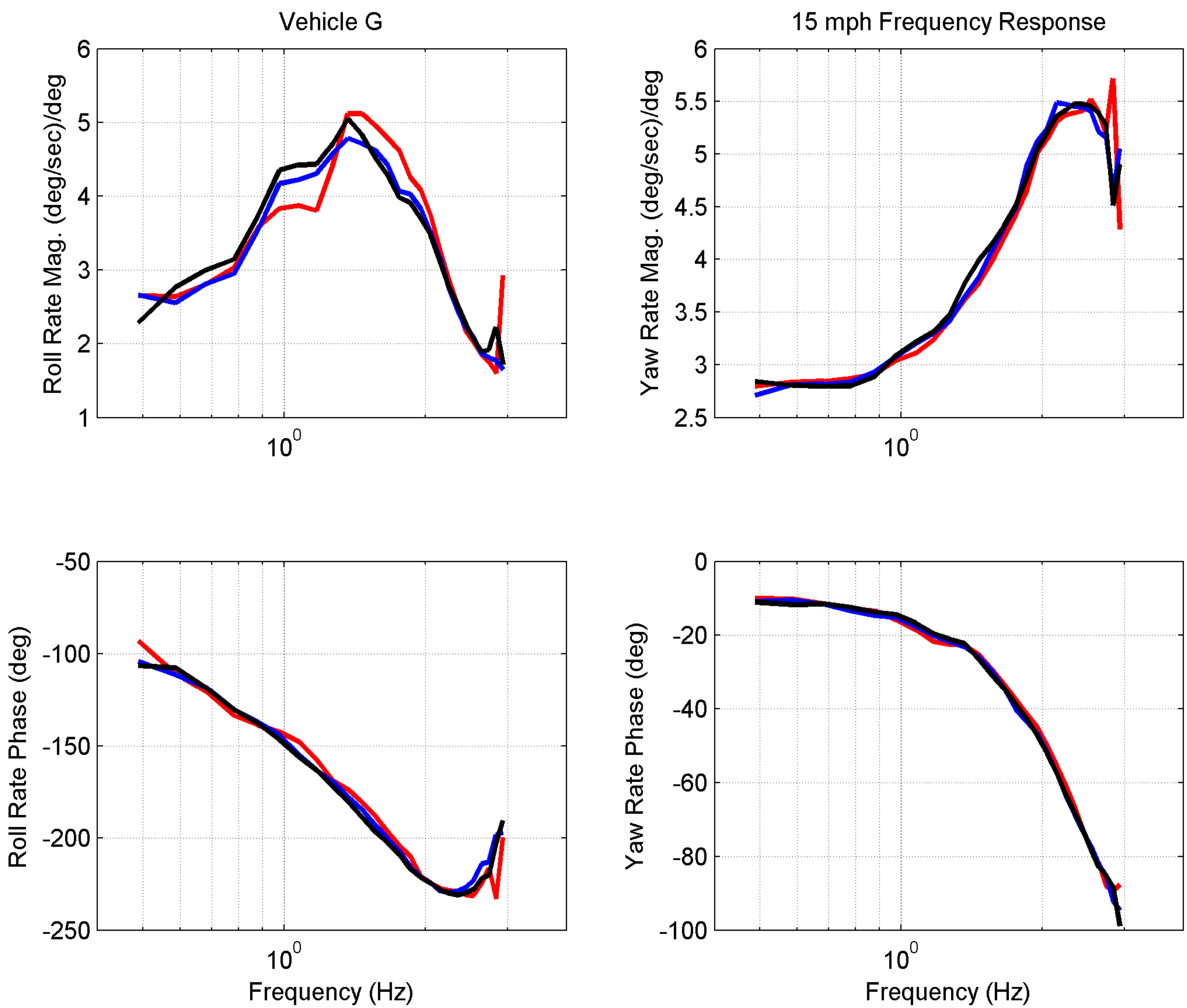

Vehicle G
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle G
Left Flick Test
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
Time (sec)
0
1
2
3
4
Speed (mph)
30
20
10
0
Roll Angle (deg)
10
5
0
-5
Lateral Acceleration (g)
0.4
0.2
0
-0.2
-0.4
-0.6
Yaw Rate (deg/sec)
100
50
0
-50
-100

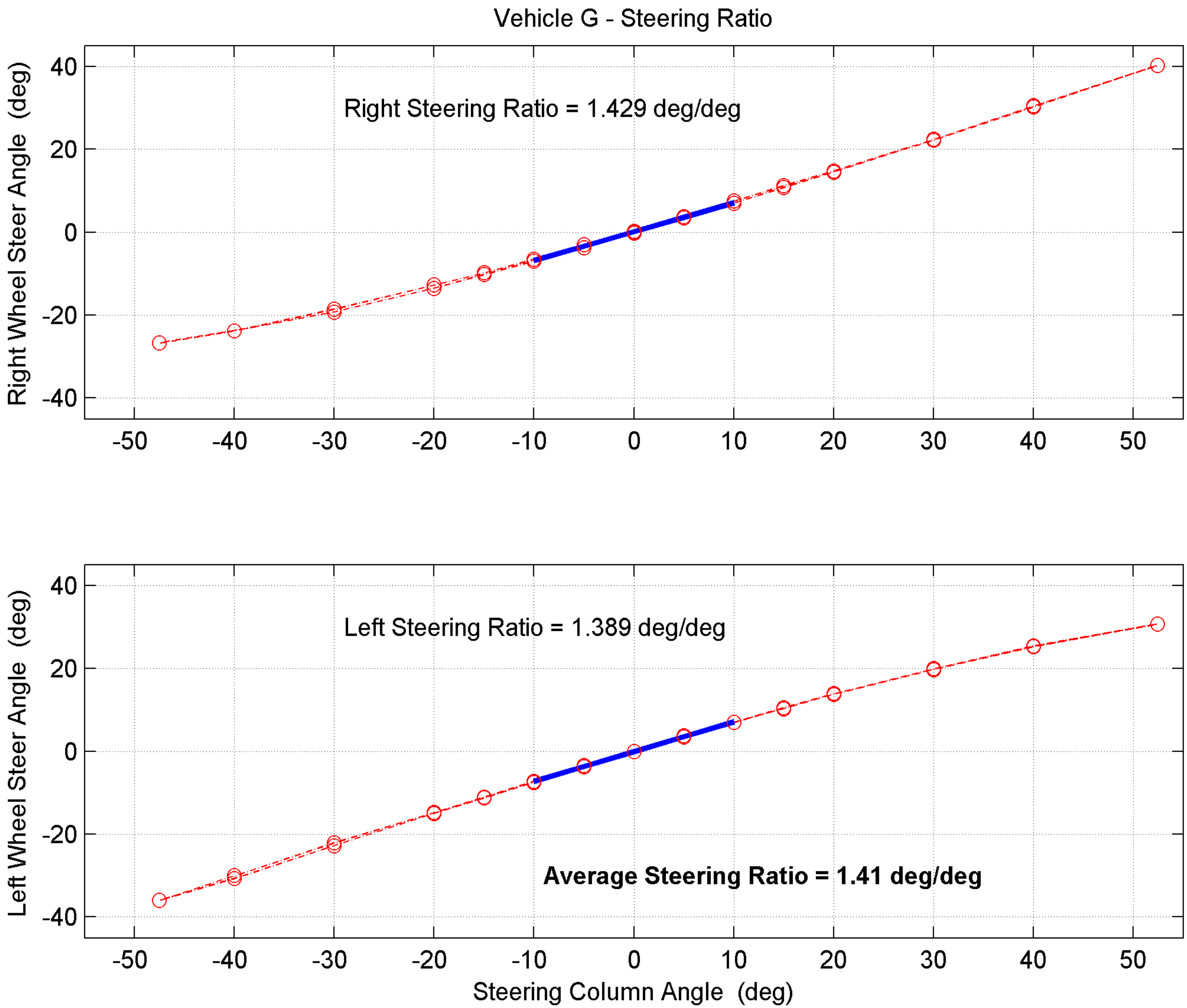

Representative Sine Sweep Time Domain Plots - Vehicle G
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

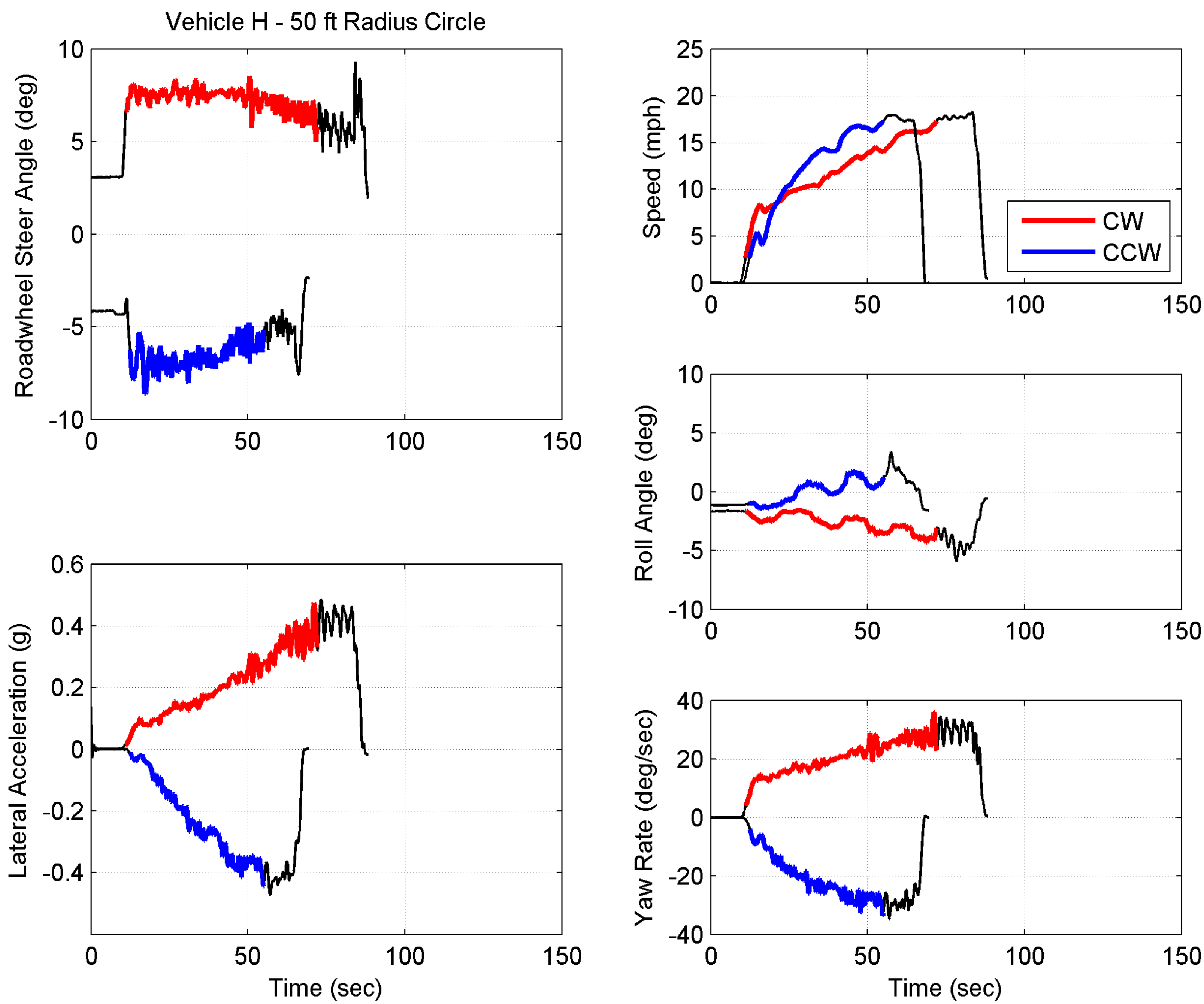


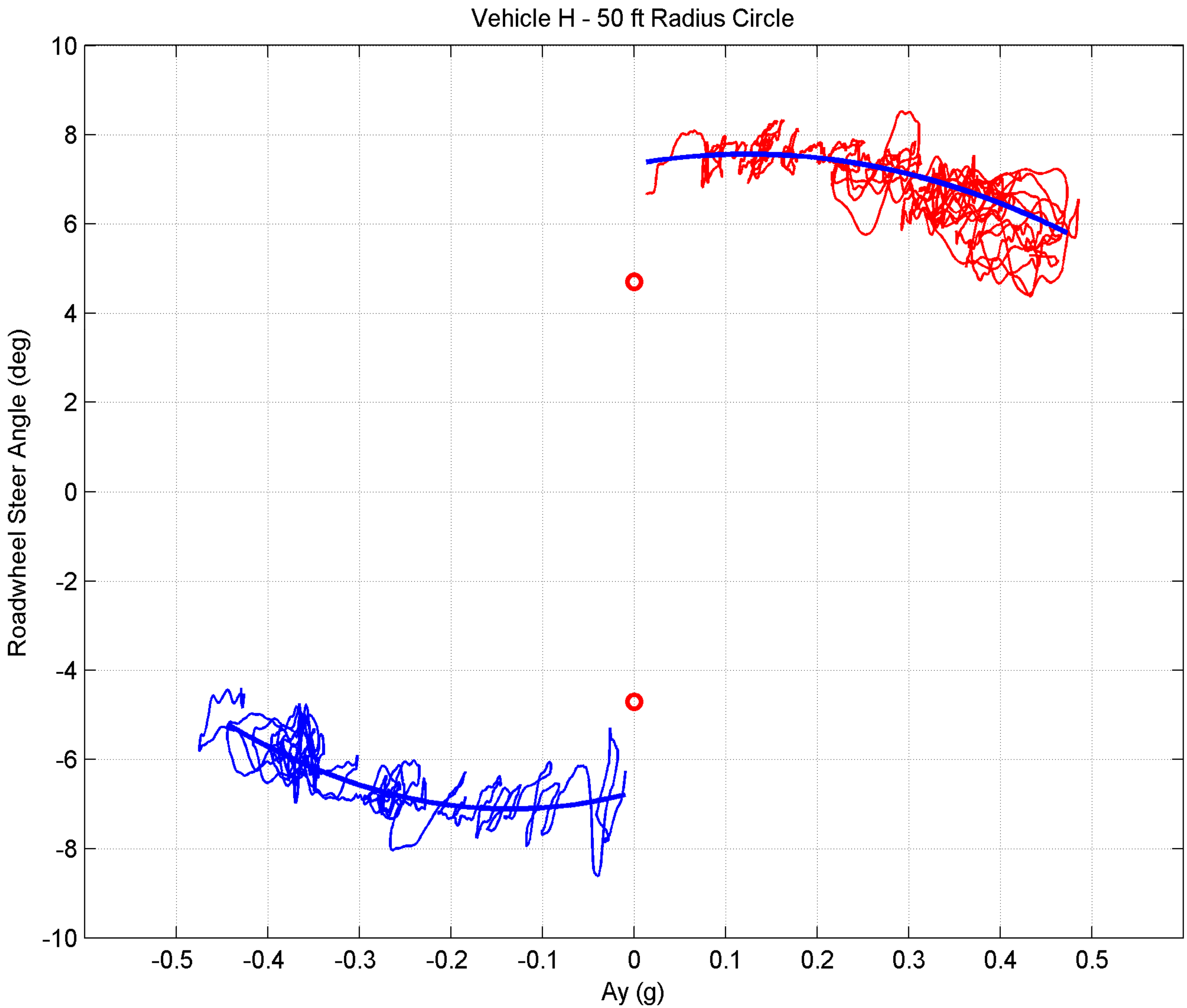
Vehicle G
15 mph Frequency Response
Ay Mag. (g/deg)
0.06
0.05
0.04
0.03
0.02
0.01
0
Roll Angle Mag. (deg/deg)
0.8
0.6
0.4
0.2
0
Ay Phase (deg)
50
0
-50
-100
-150
Roll Angle Phase (deg)
-180
-200
-220
-240
-260
-280
-300
-320
10^0
Frequency (Hz)



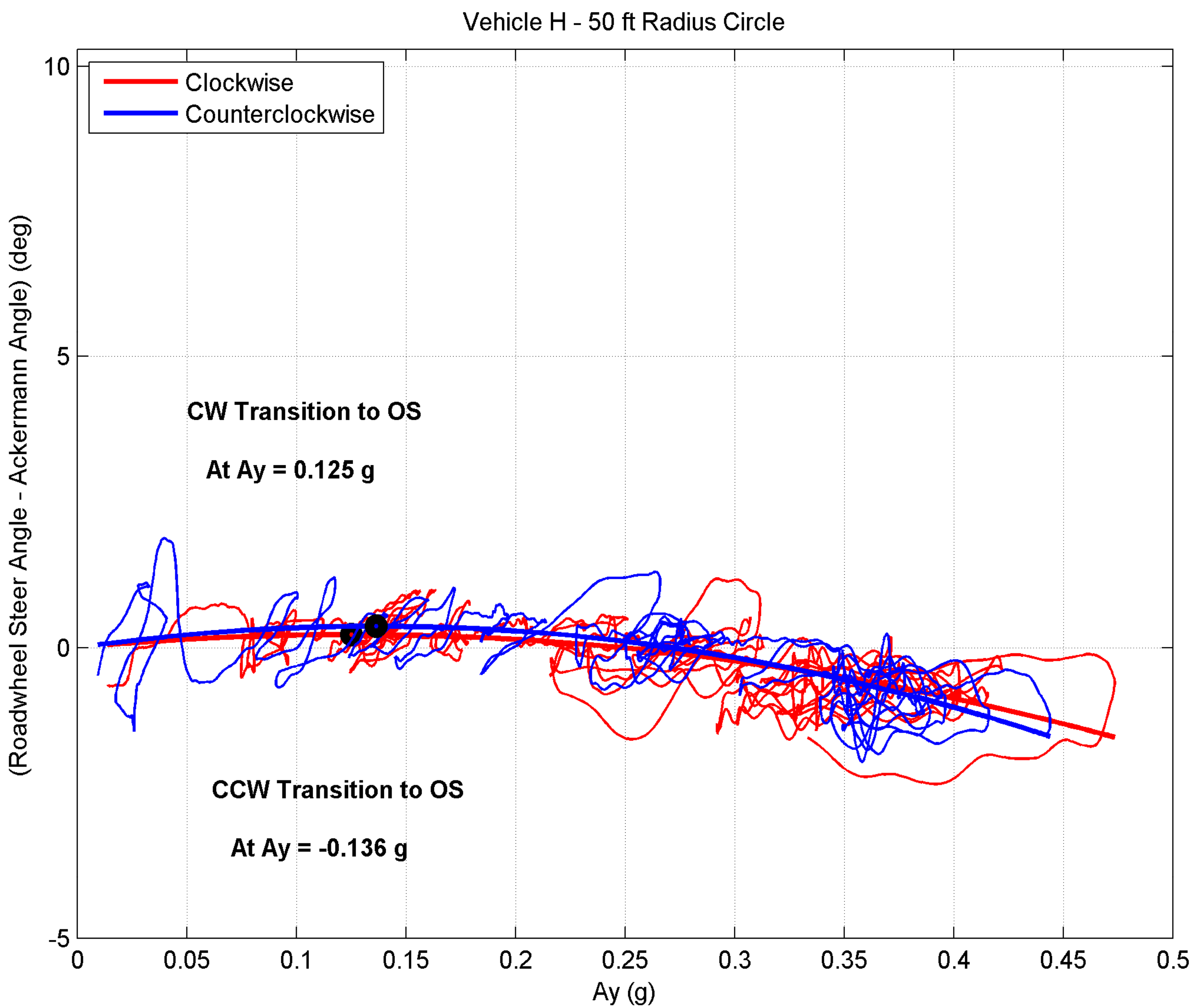
Vehicle G
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
10^0
6
5
4
3
2
1
5.5
4.5
3.5
2.5
-50
-100
-150
-200
-250
0
-20
-40
-60
-80

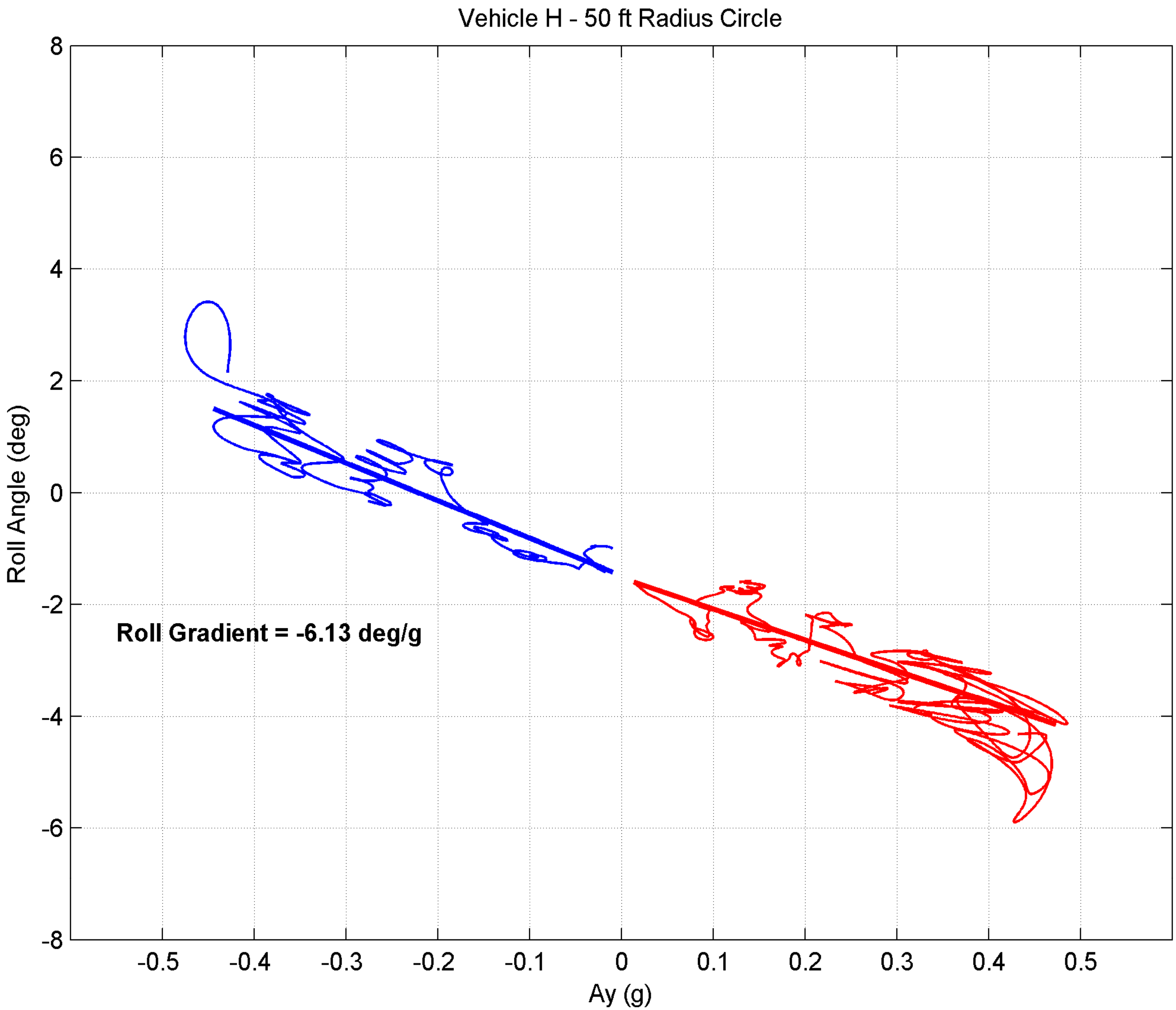

Vehicle G - Steering Ratio
Right Steering Ratio = 1.429 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-50
-40
-30
-20
-10
0
10
20
30
40
50
Left Steering Ratio = 1.389 deg/deg
Average Steering Ratio = 1.41 deg/deg
Left Wheel Steer Angle (deg)
Steering Column Angle (deg)


Vehicle H - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
CW
CCW
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

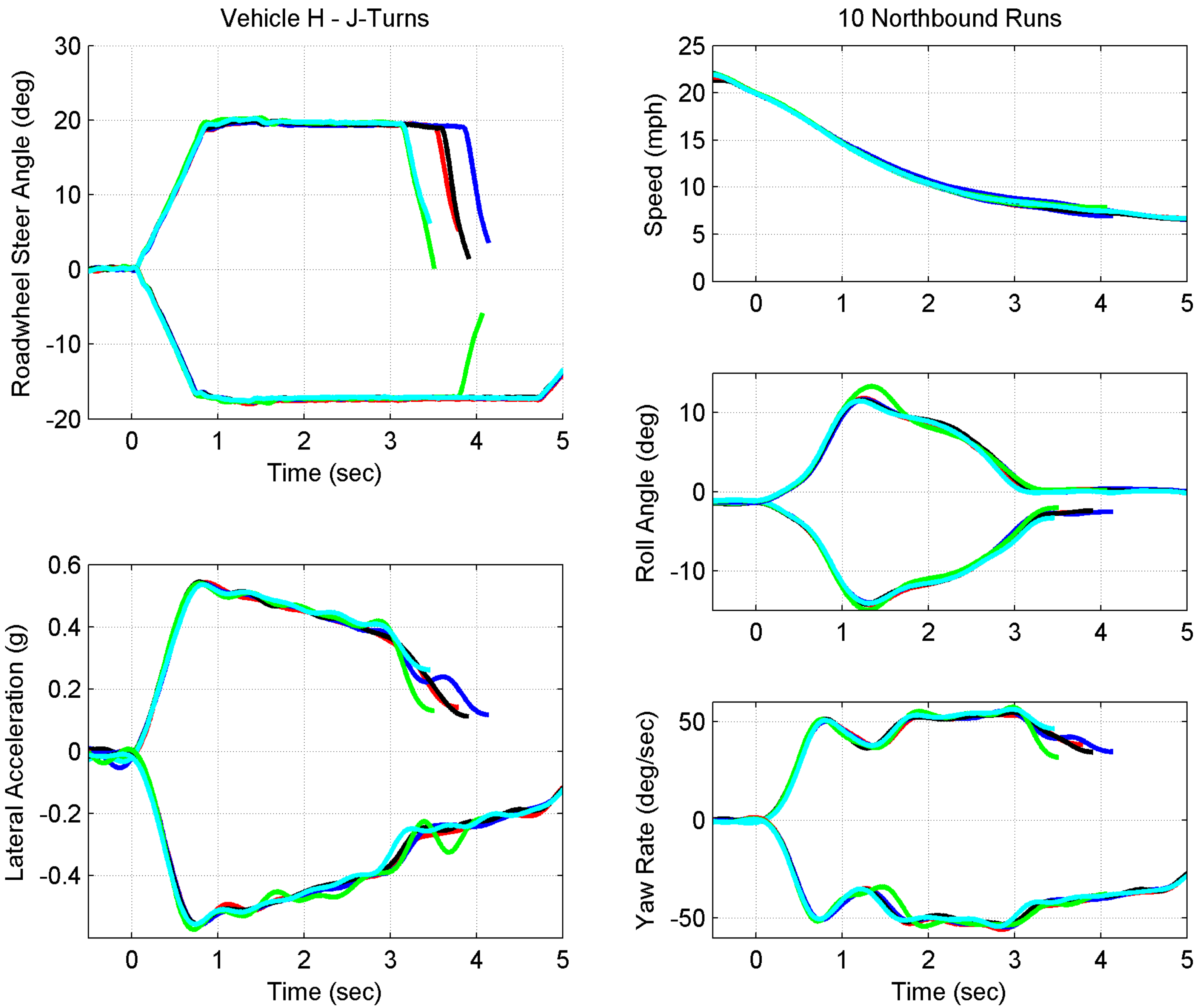


Vehicle H - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)


Vehicle H - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.125 g
CCW Transition to OS
At Ay = -0.136 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

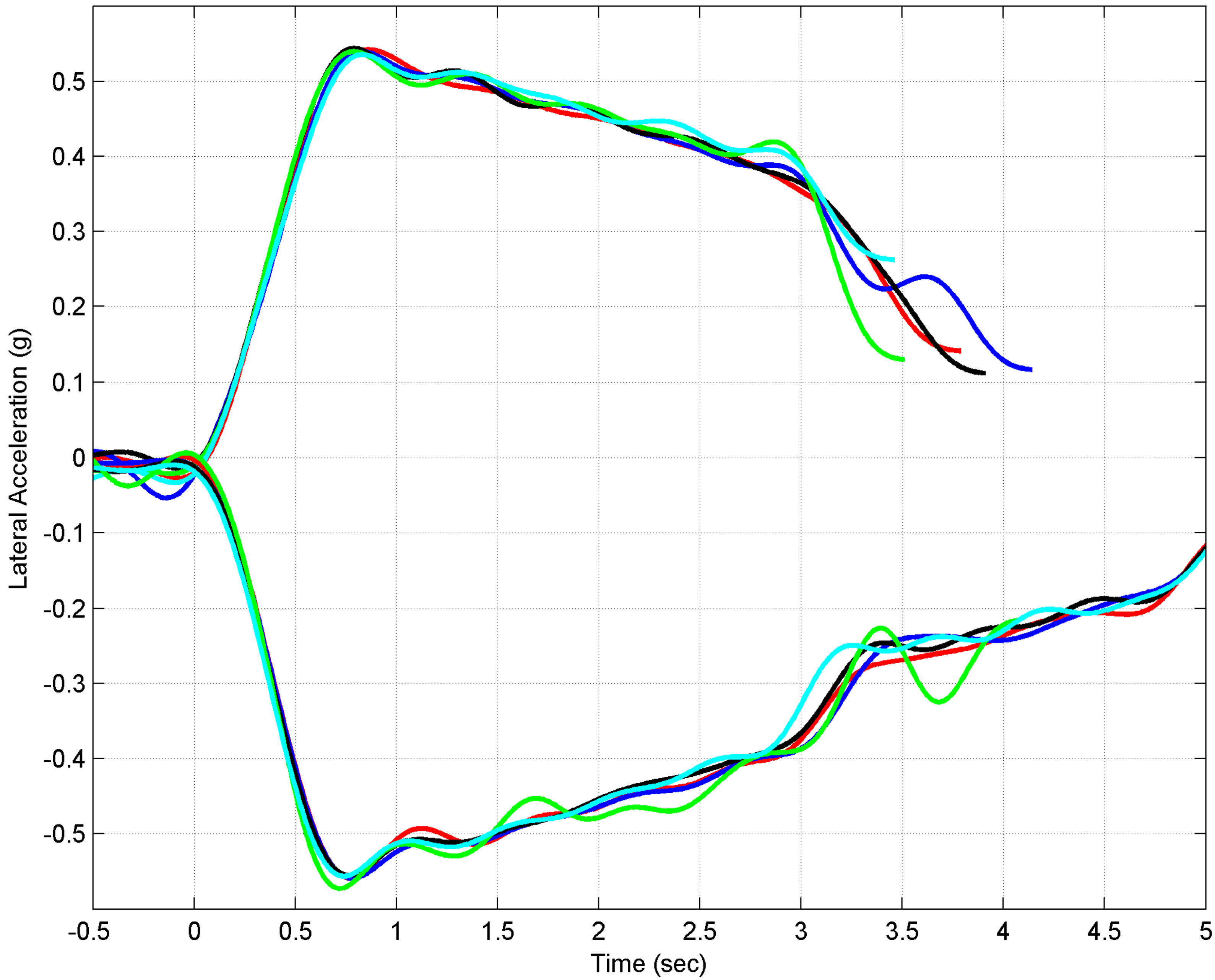


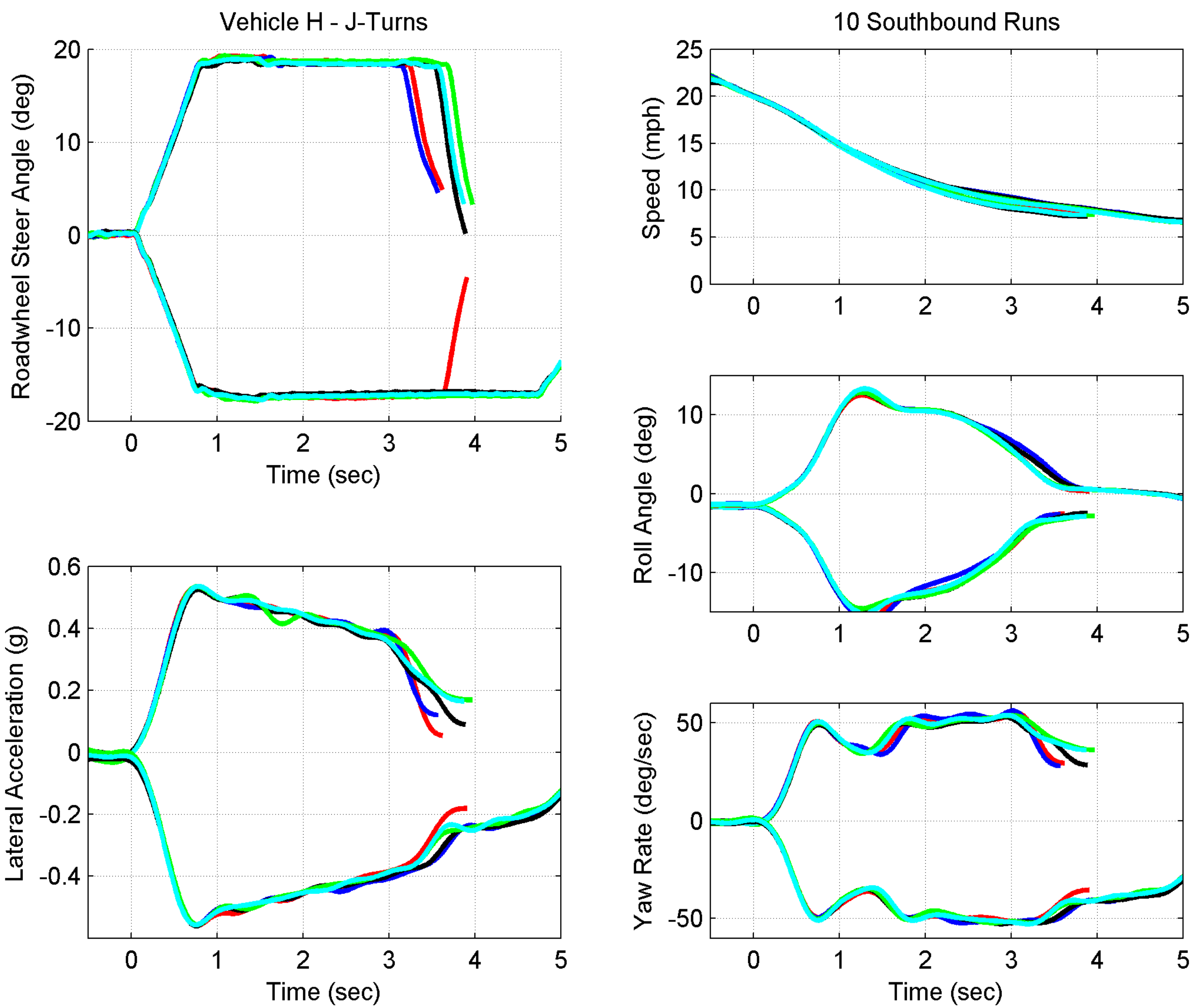
Vehicle H - 50 ft Radius Circle
Roll Angle (deg)
8
6
4
2
0
-2
-4
-6
-8
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)
Roll Gradient = -6.13 deg/g



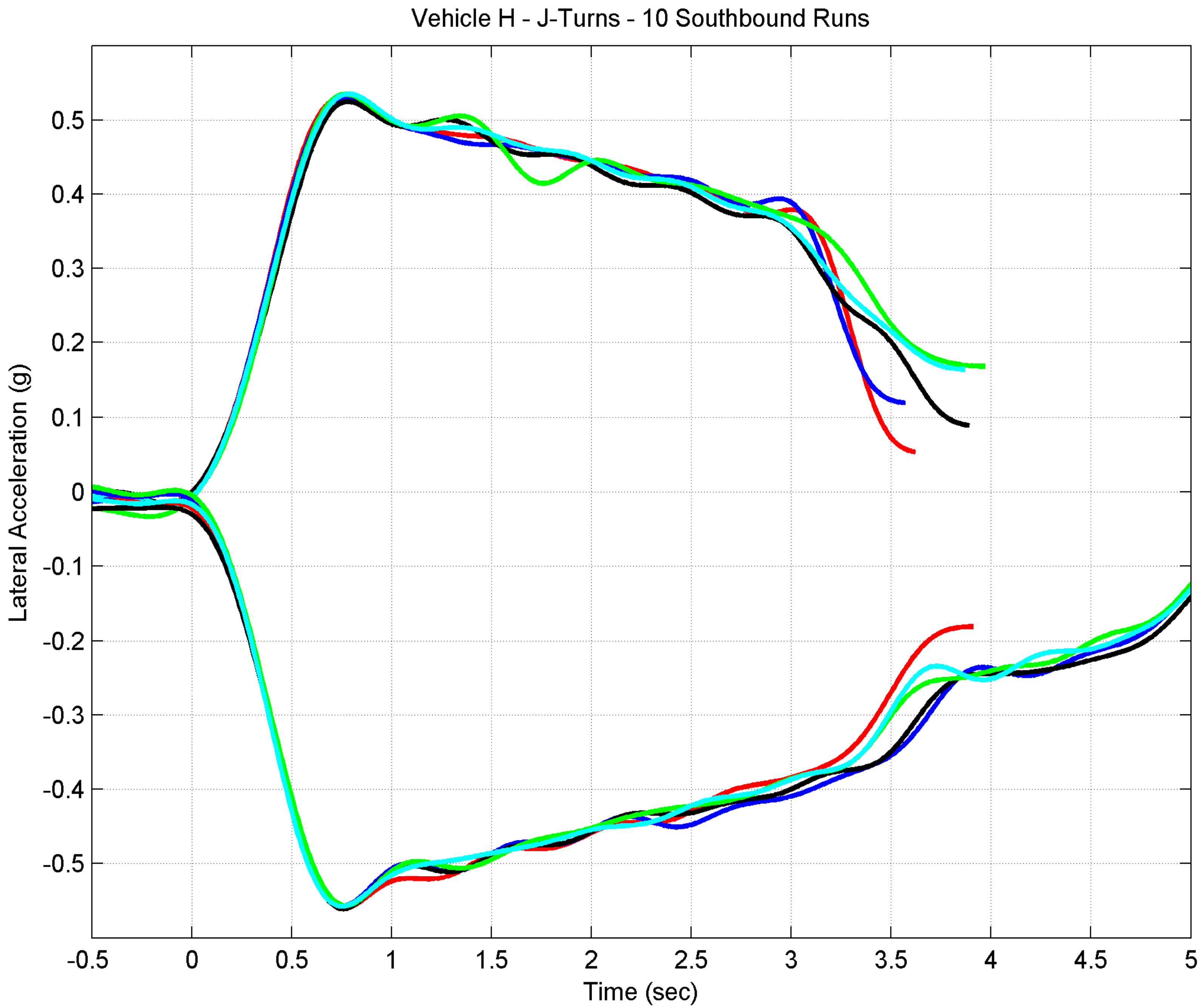
Vehicle H - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

Vehicle H - J-Turns - 10 Northbound Runs





Vehicle H - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



Vehicle H - J-Turns - 10 Southbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle H

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.5419	-0.5591
2	0.5403	-0.5596
3	0.5437	-0.5553
4	0.5396	-0.5730
5	0.5354	-0.5566
Mean Value of 5 Runs	0.5402	-0.5607
Standard Deviation of 5 Runs	0.003	0.007

Average of 10 Northbound Runs

0.5504

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.5297	-0.5605
2	0.5286	-0.5571
3	0.5248	-0.5613
4	0.5346	-0.5567
5	0.5350	-0.5577
Mean Value of 5 Runs	0.5306	-0.5587
Standard Deviation of 5 Runs	0.004	0.002

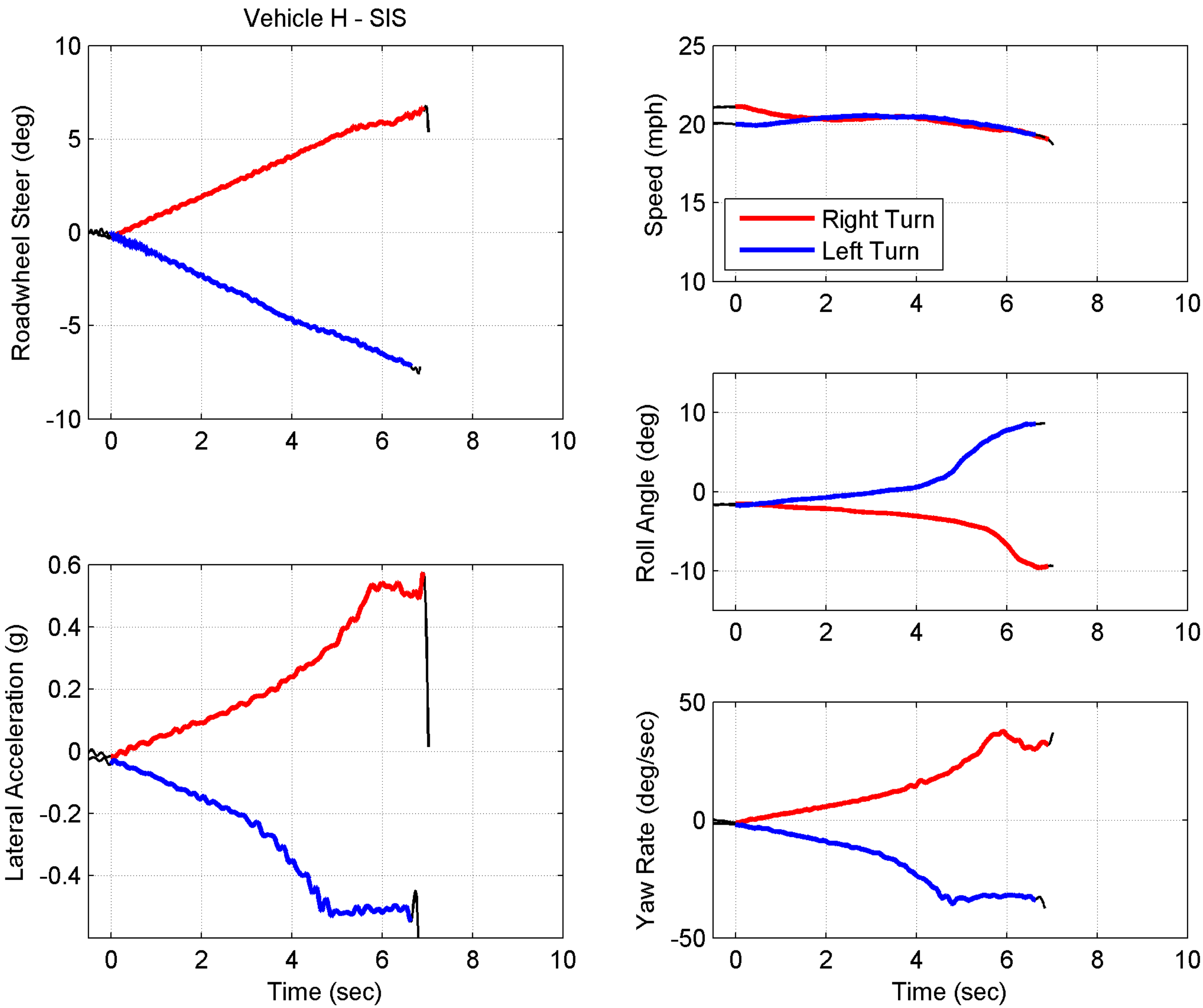
Average of 10 Southbound Runs

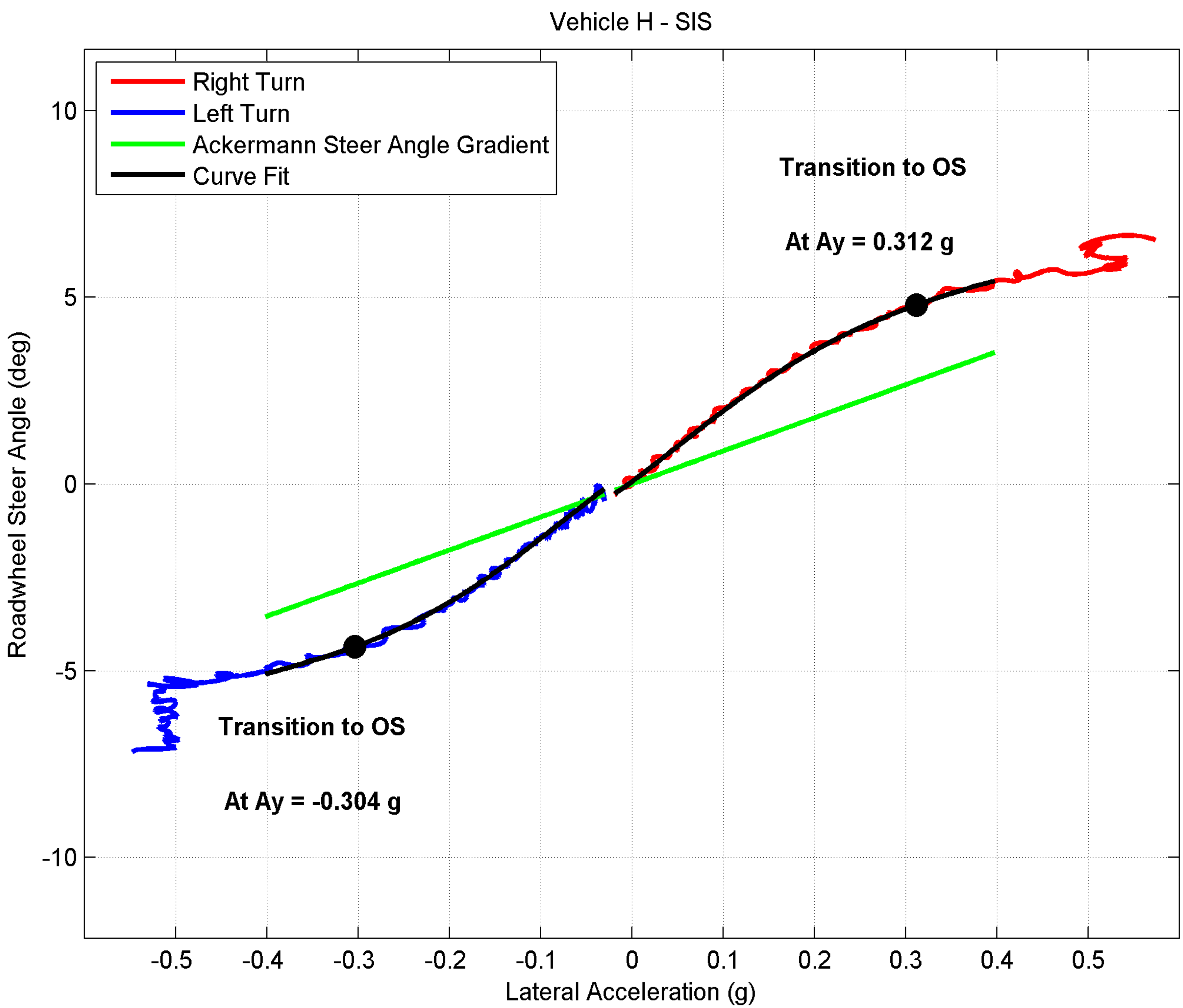
0.5446

Average of All 20 Runs

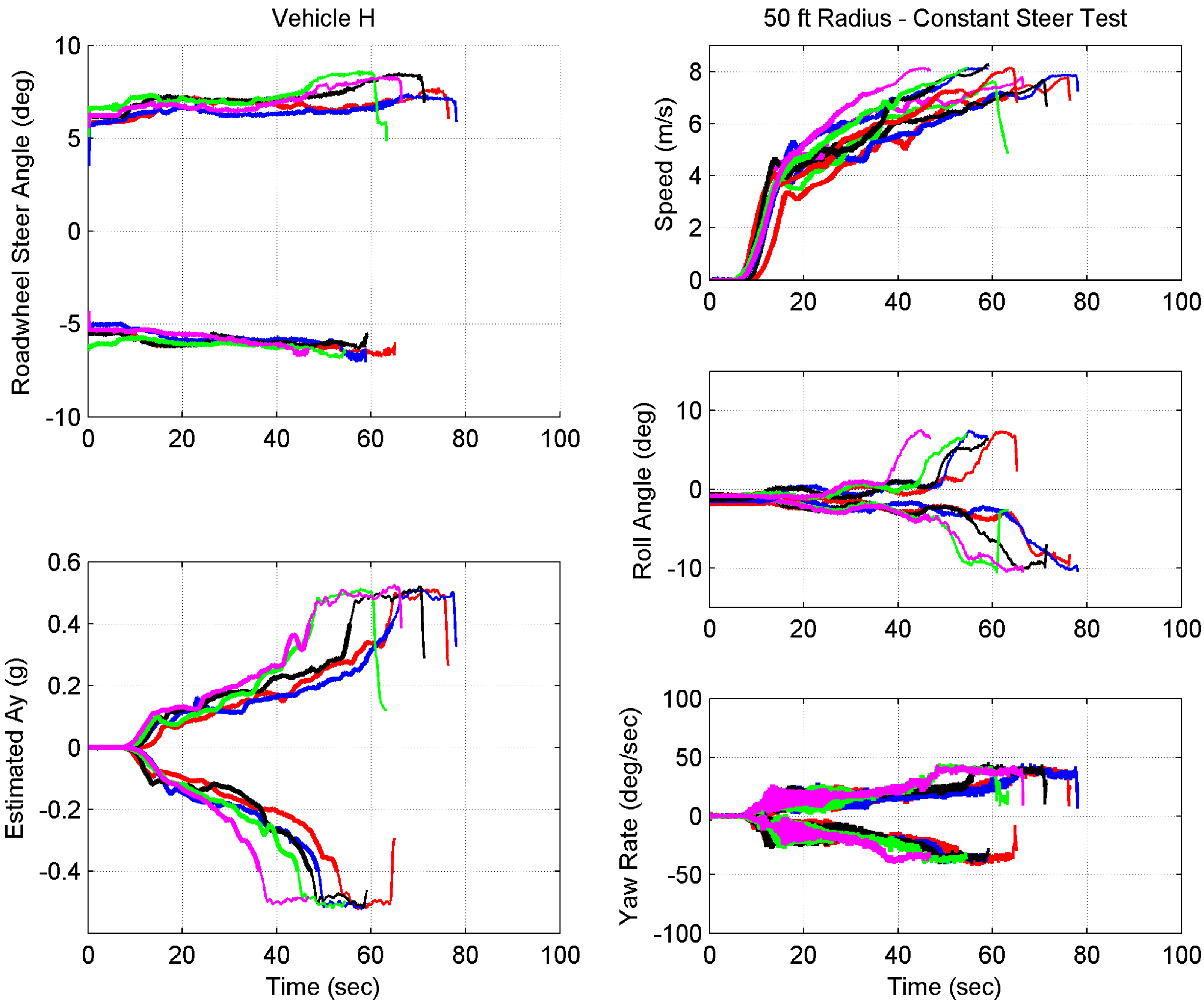
0.548

Threshold Ay

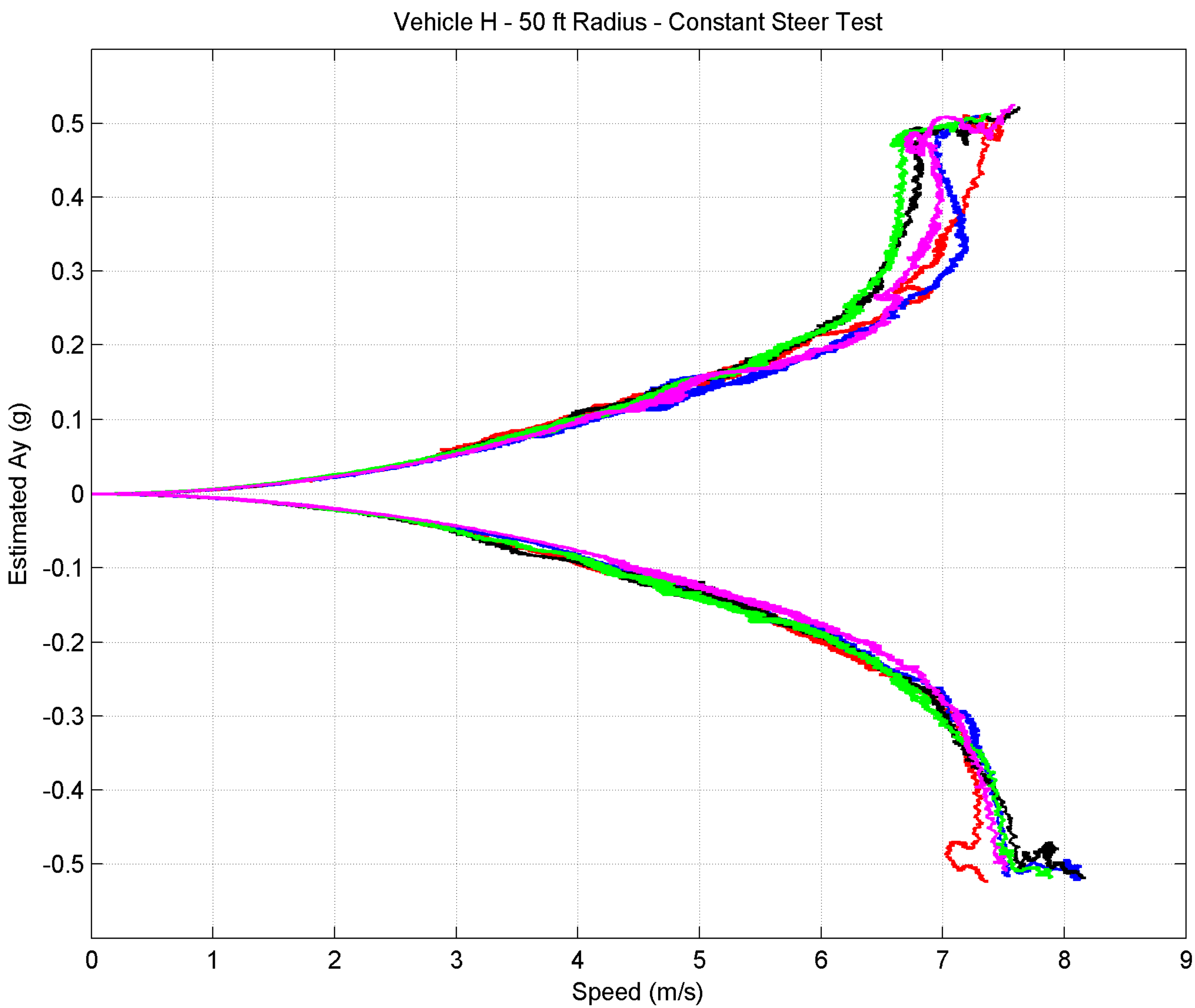

Vehicle H - SIS
Roadwheel Steer (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

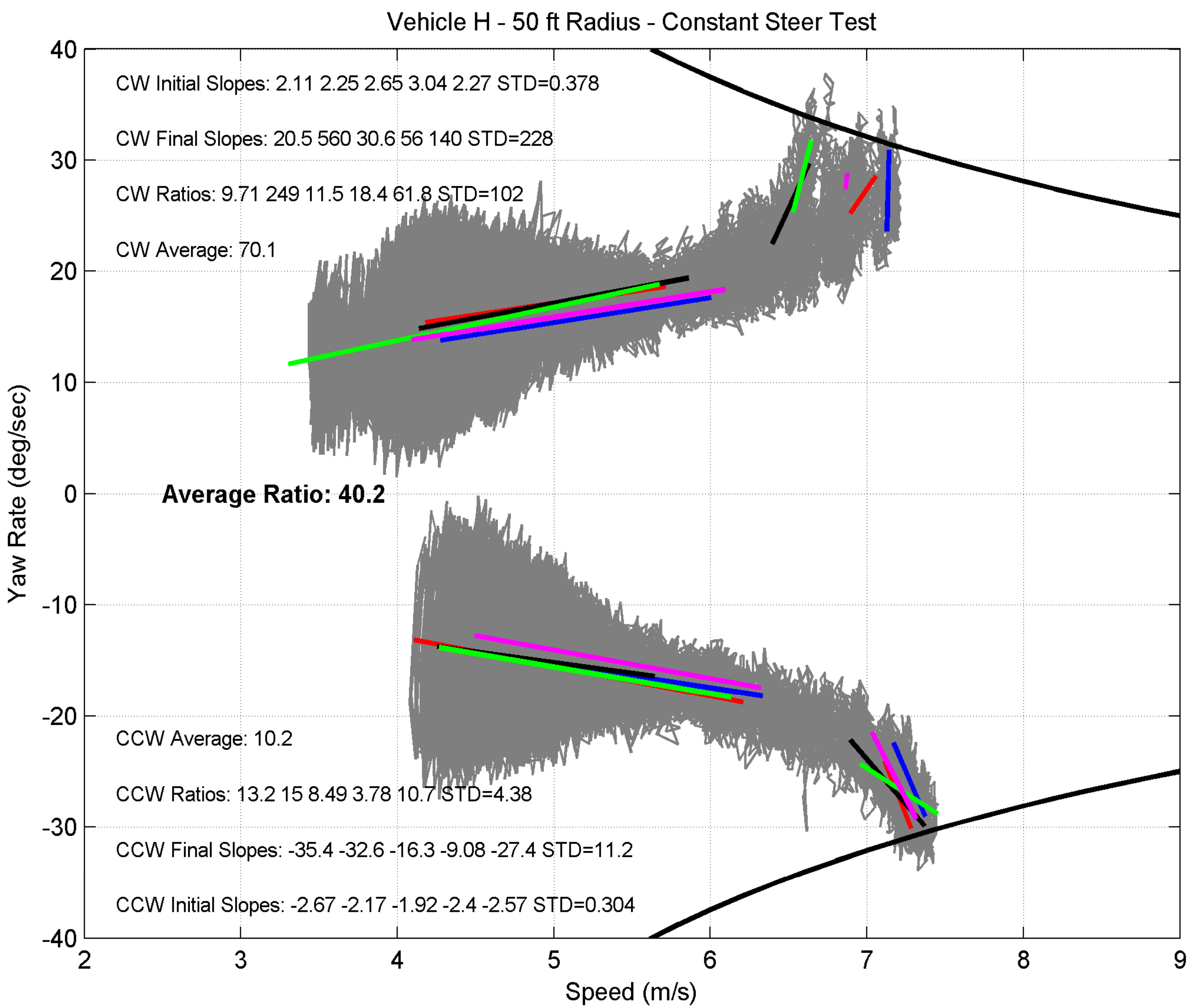


Vehicle H - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to OS
At Ay = 0.312 g
Transition to OS
At Ay = -0.304 g
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
10
5
0
-5
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

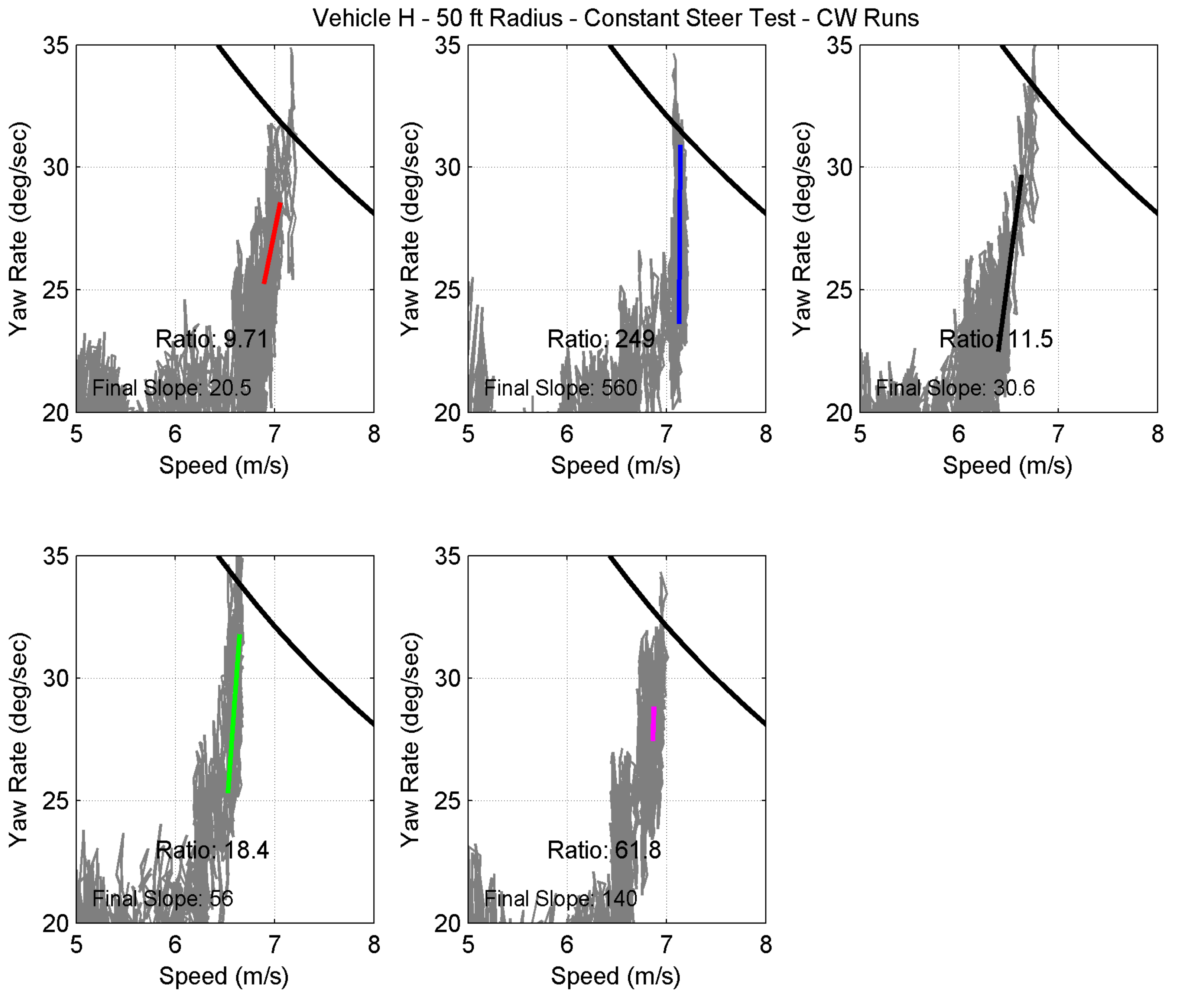


Vehicle H
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

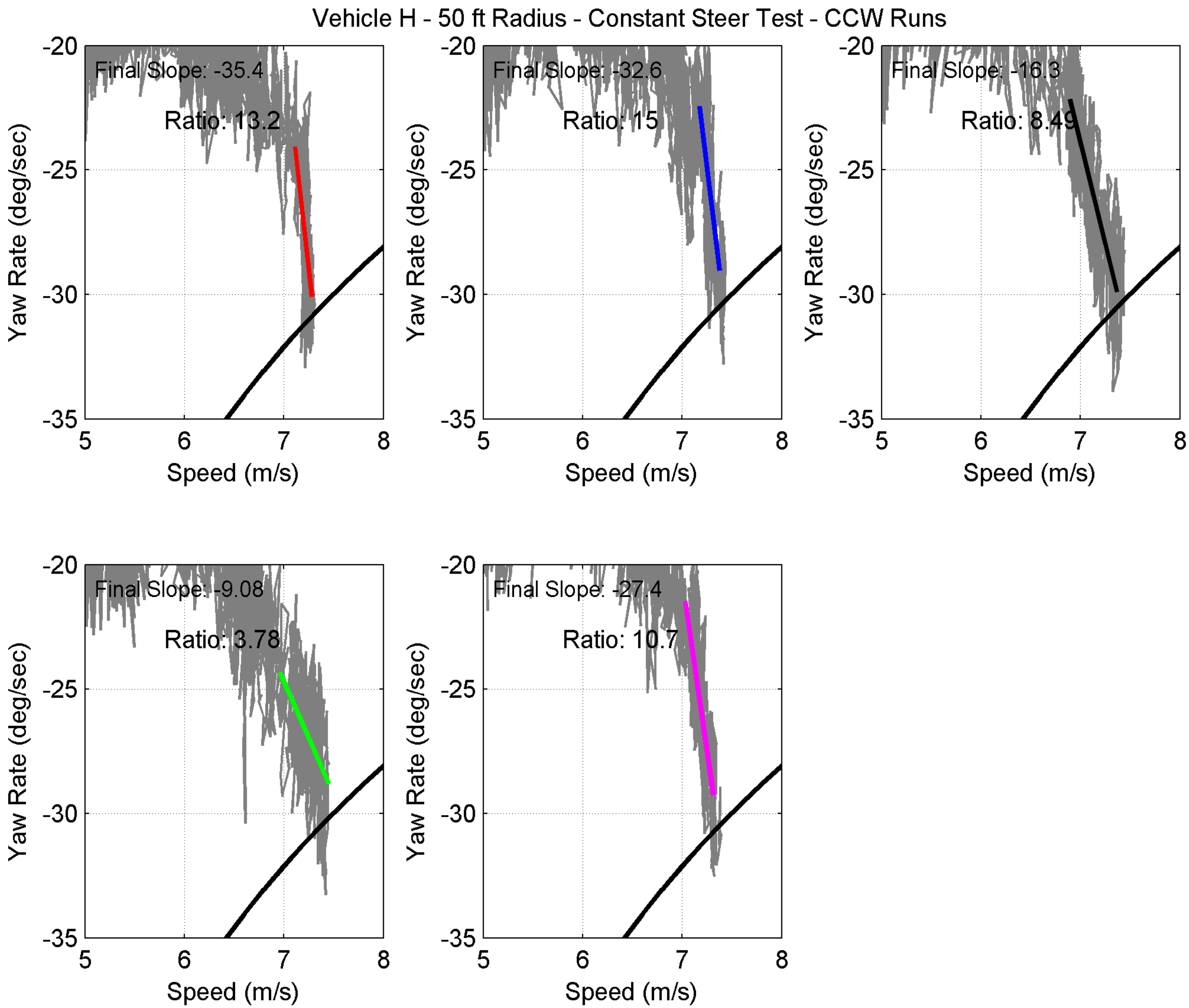

Vehicle H - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9



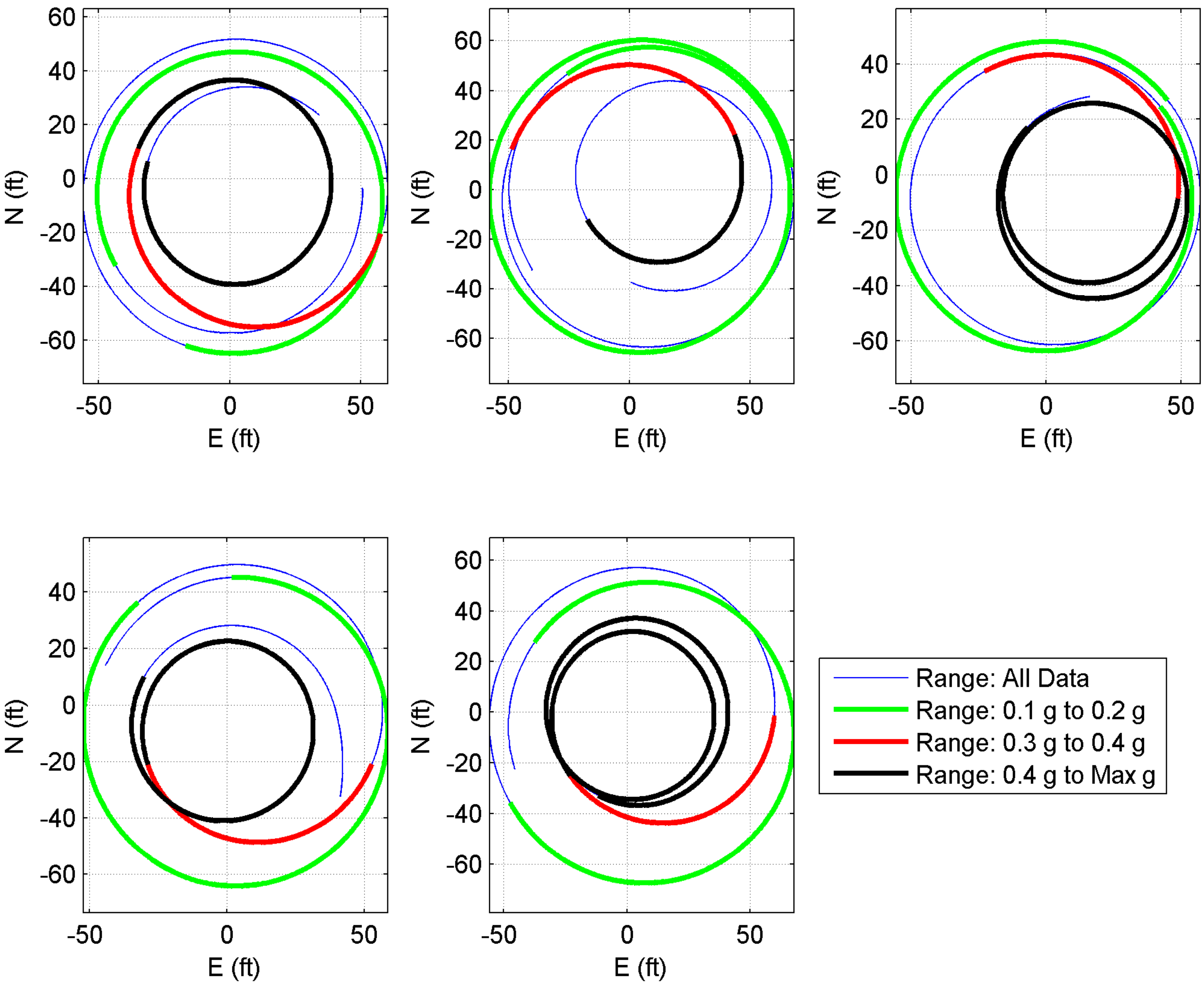
Vehicle H - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 2.11 2.25 2.65 3.04 2.27 STD=0.378
CW Final Slopes: 20.5 560 30.6 56 140 STD=228
CW Ratios: 9.71 249 11.5 18.4 61.8 STD=102
CW Average: 70.1
Average Ratio: 40.2
CCW Average: 10.2
CCW Ratios: 13.2 15 8.49 3.78 10.7 STD=4.38
CCW Final Slopes: -35.4 -32.6 -16.3 -9.08 -27.4 STD=11.2
CCW Initial Slopes: -2.67 -2.17 -1.92 -2.4 -2.57 STD=0.304
Yaw Rate (deg/sec)
Speed (m/s)
40
30
20
10
0
-10
-20
-30
-40
2
3
4
5
6
7
8
9

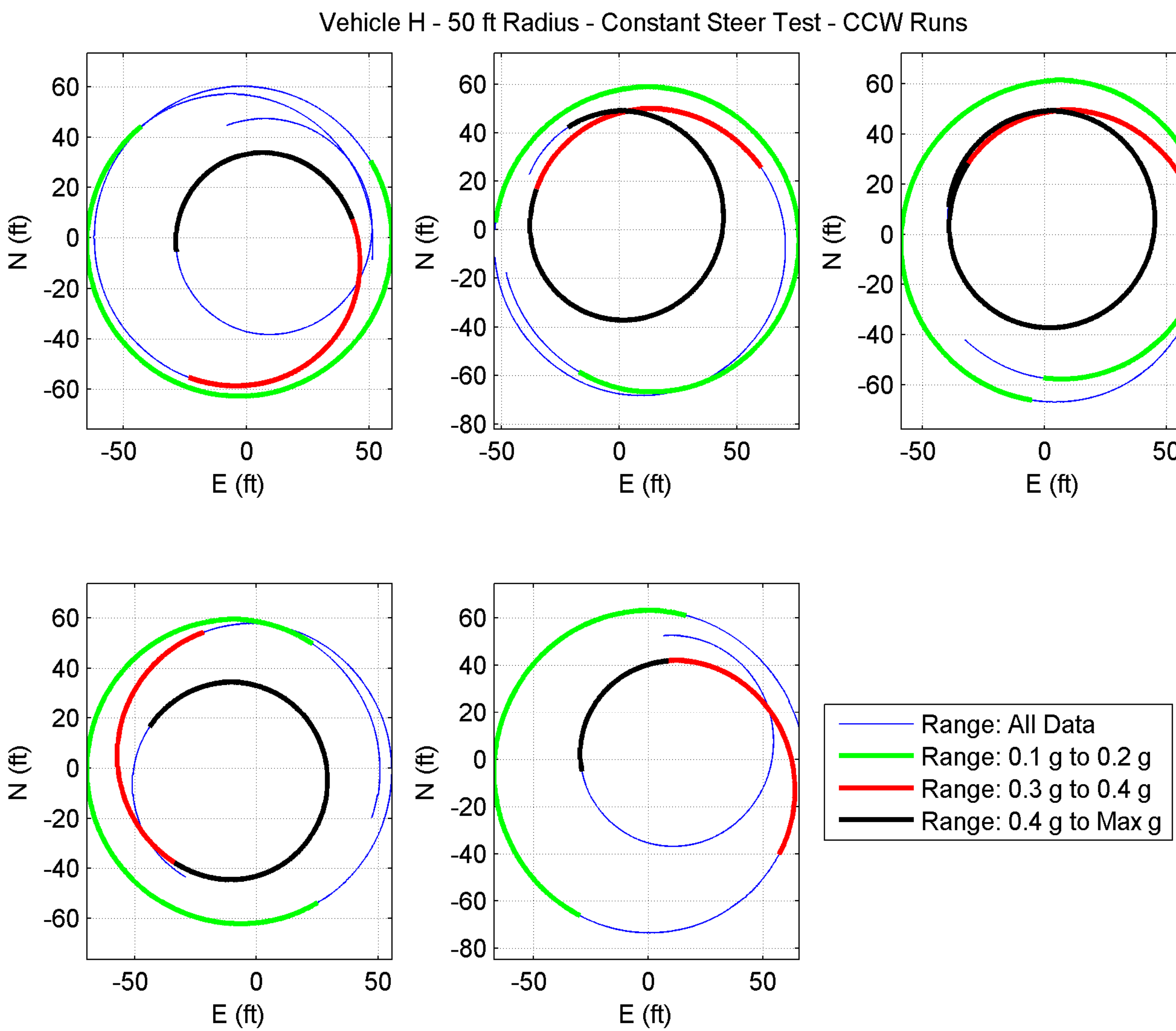


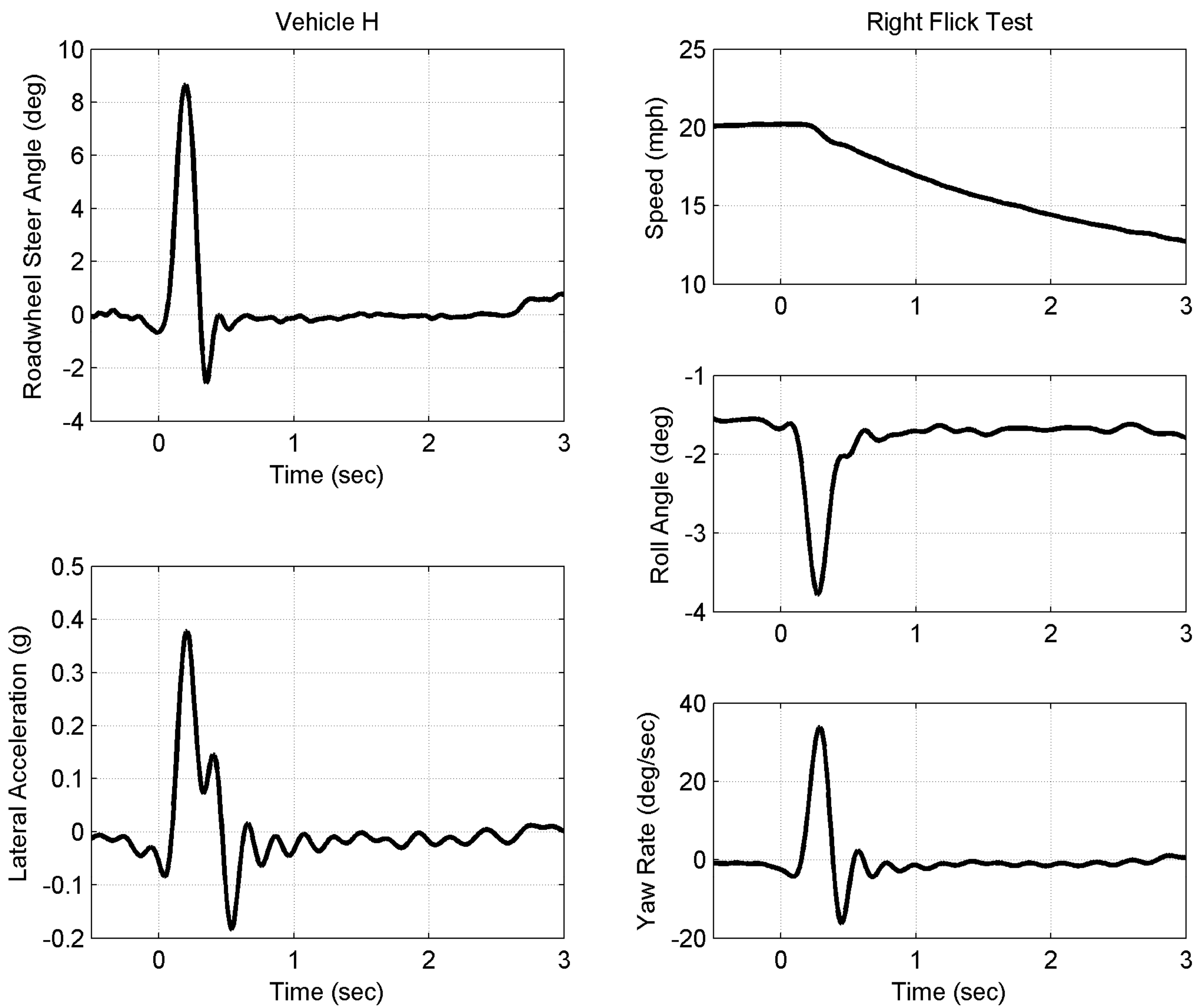
Vehicle H - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 9.71
Final Slope: 20.5
Ratio: 249
Final Slope: 560
Ratio: 11.5
Final Slope: 30.6
Ratio: 18.4
Final Slope: 56
Ratio: 61.8
Final Slope: 140

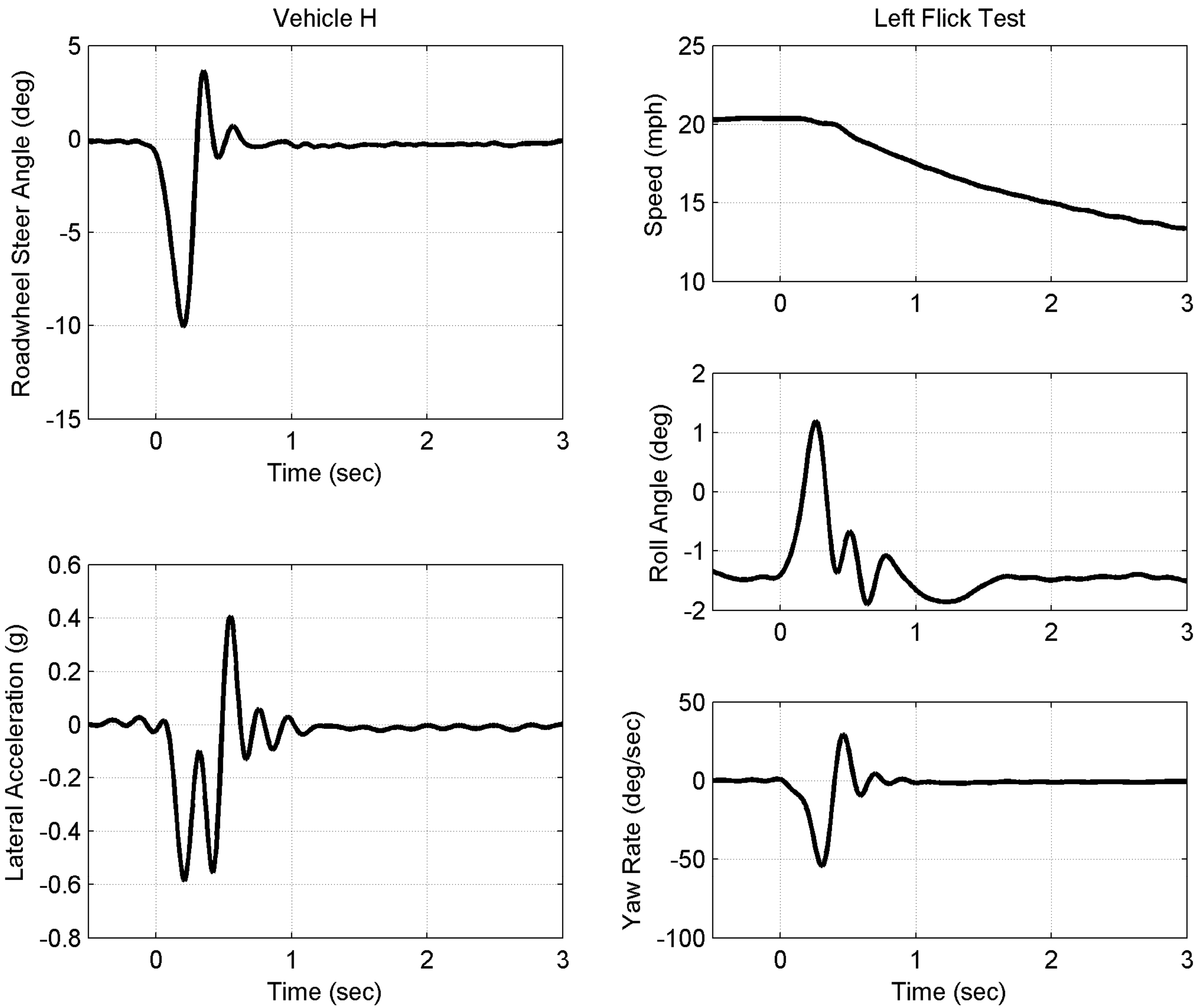

Vehicle H - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -35.4
Ratio: 13.2
Final Slope: -32.6
Ratio: 15
Final Slope: -16.3
Ratio: 8.49
Final Slope: -9.08
Ratio: 3.78
Final Slope: -27.4
Ratio: 10.7
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
5
6
7
8

Vehicle H - 50 ft Radius - Constant Steer Test - CW Runs

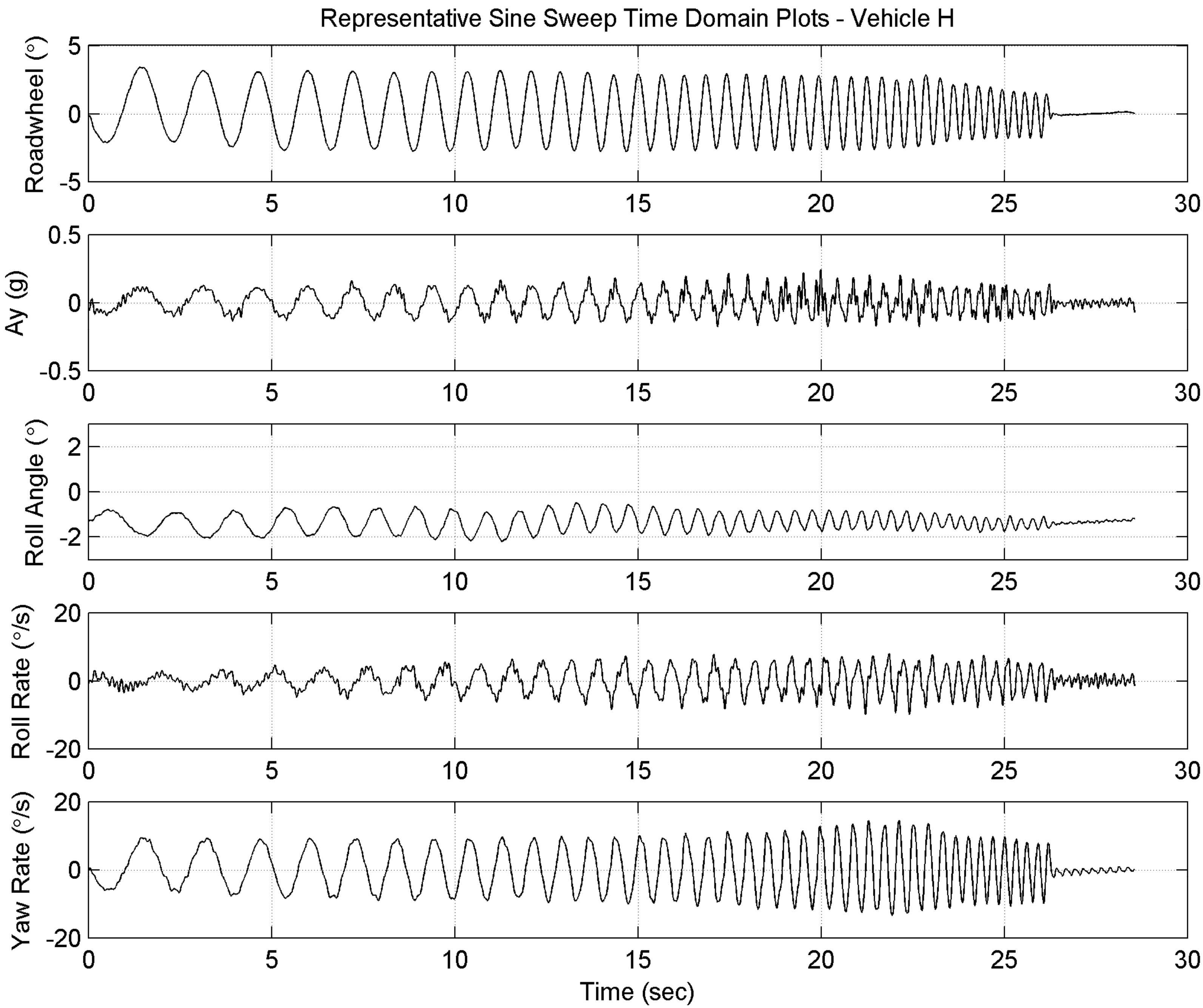



Vehicle H - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

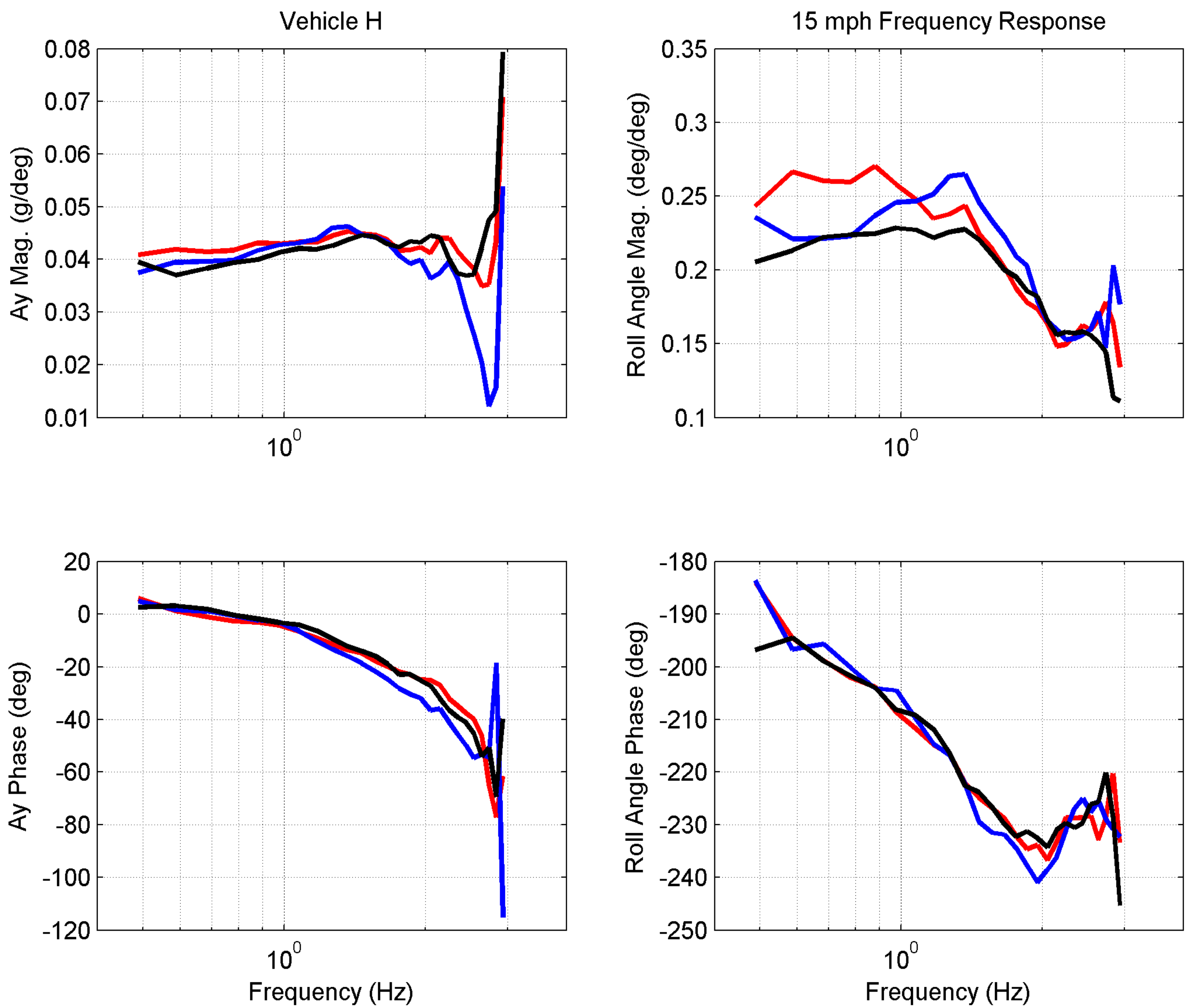

Vehicle H
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)



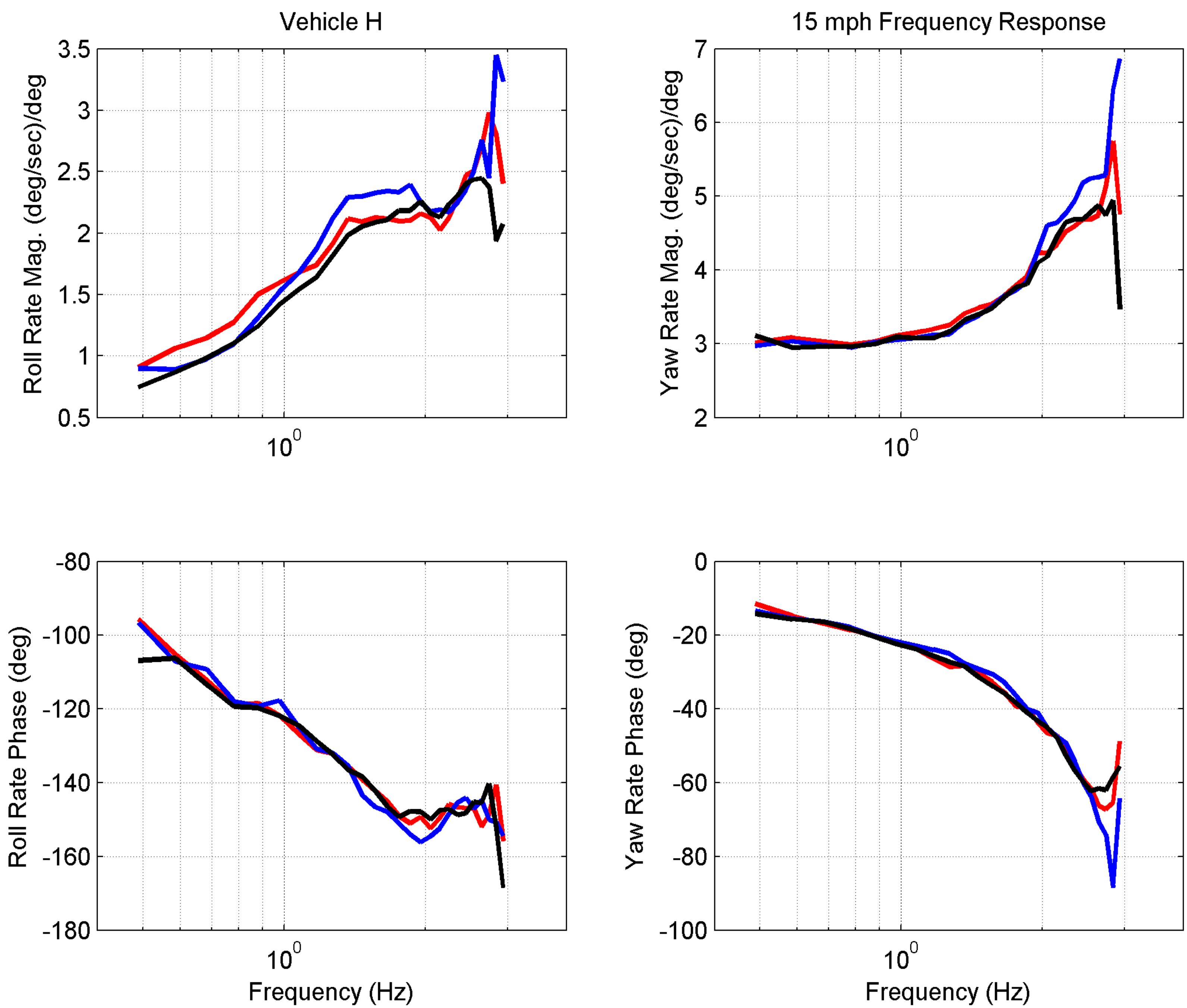
Vehicle H
Left Flick Test
Roadwheel Steer Angle (deg)
5
0
-5
-10
-15
Time (sec)
0
1
2
3
Speed (mph)
25
20
15
10
Roll Angle (deg)
2
1
0
-1
-2
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
50
0
-50
-100



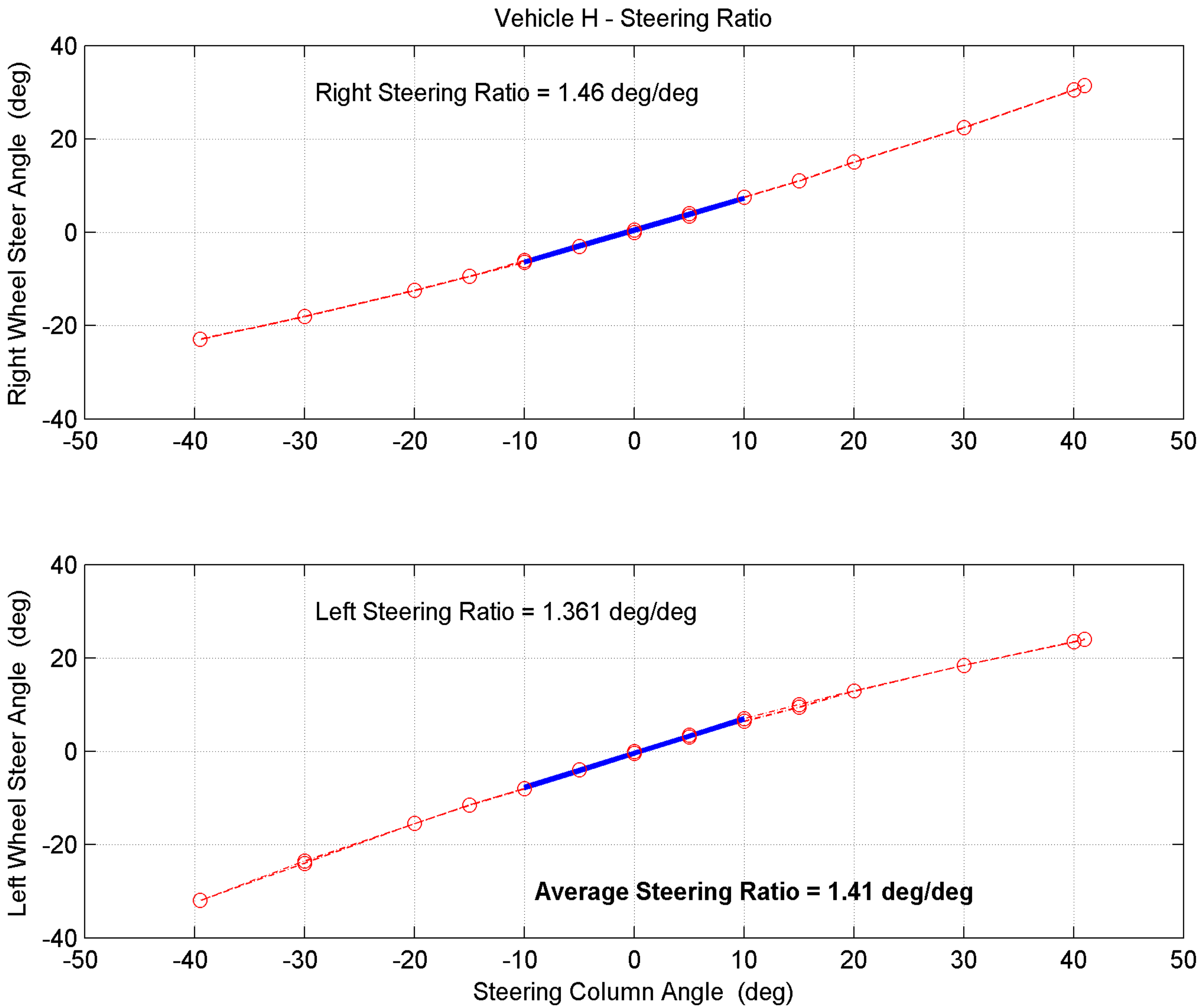
Representative Sine Sweep Time Domain Plots - Vehicle H
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)



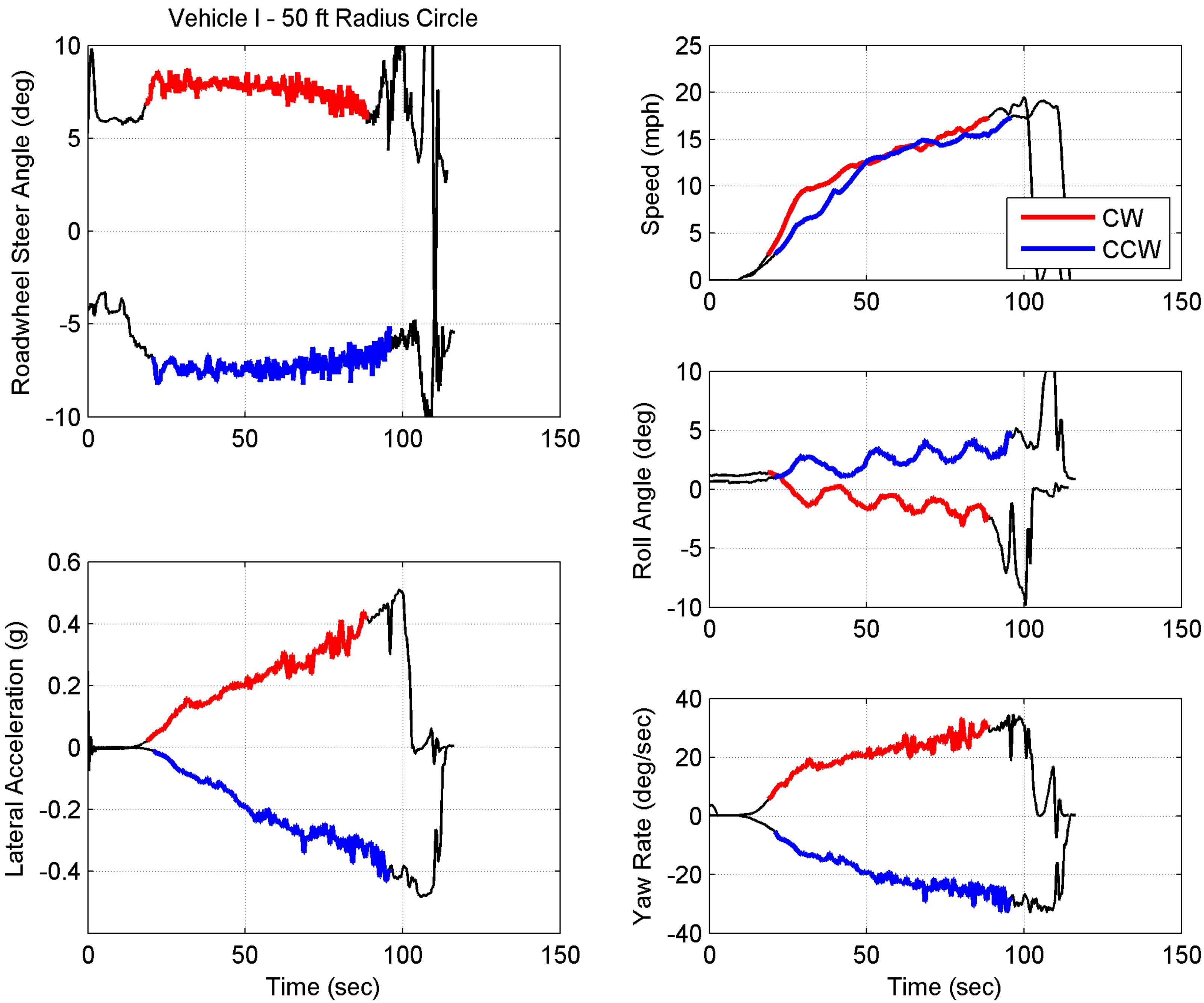
Vehicle H
15 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Frequency (Hz)
Frequency (Hz)



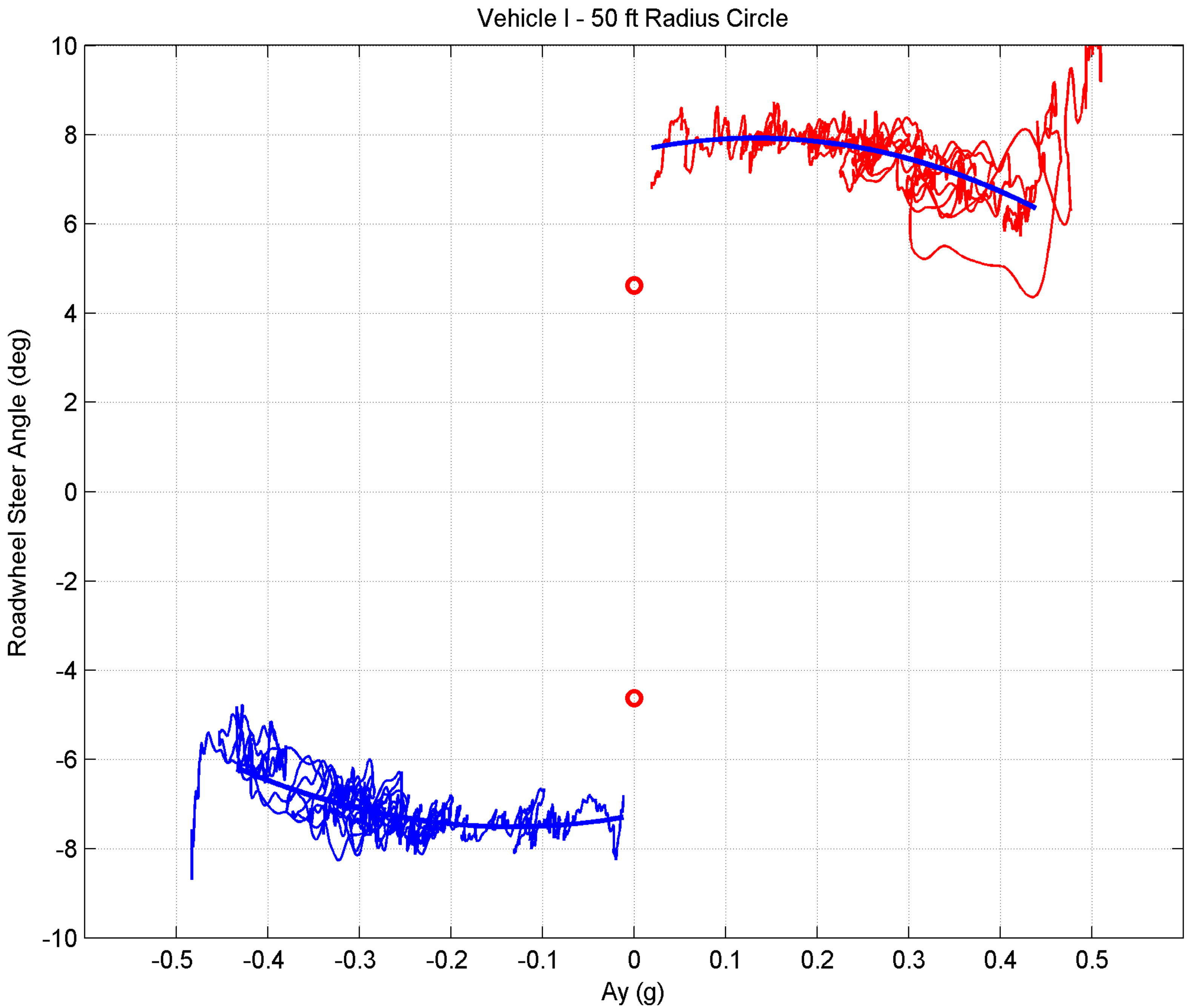
Vehicle H
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
3.5
3
2.5
2
1.5
1
0.5
10^0
Yaw Rate Mag. (deg/sec)/deg
7
6
5
4
3
2
10^0
Roll Rate Phase (deg)
-80
-100
-120
-140
-160
-180
10^0
Frequency (Hz)
Yaw Rate Phase (deg)
0
-20
-40
-60
-80
-100
10^0
Frequency (Hz)

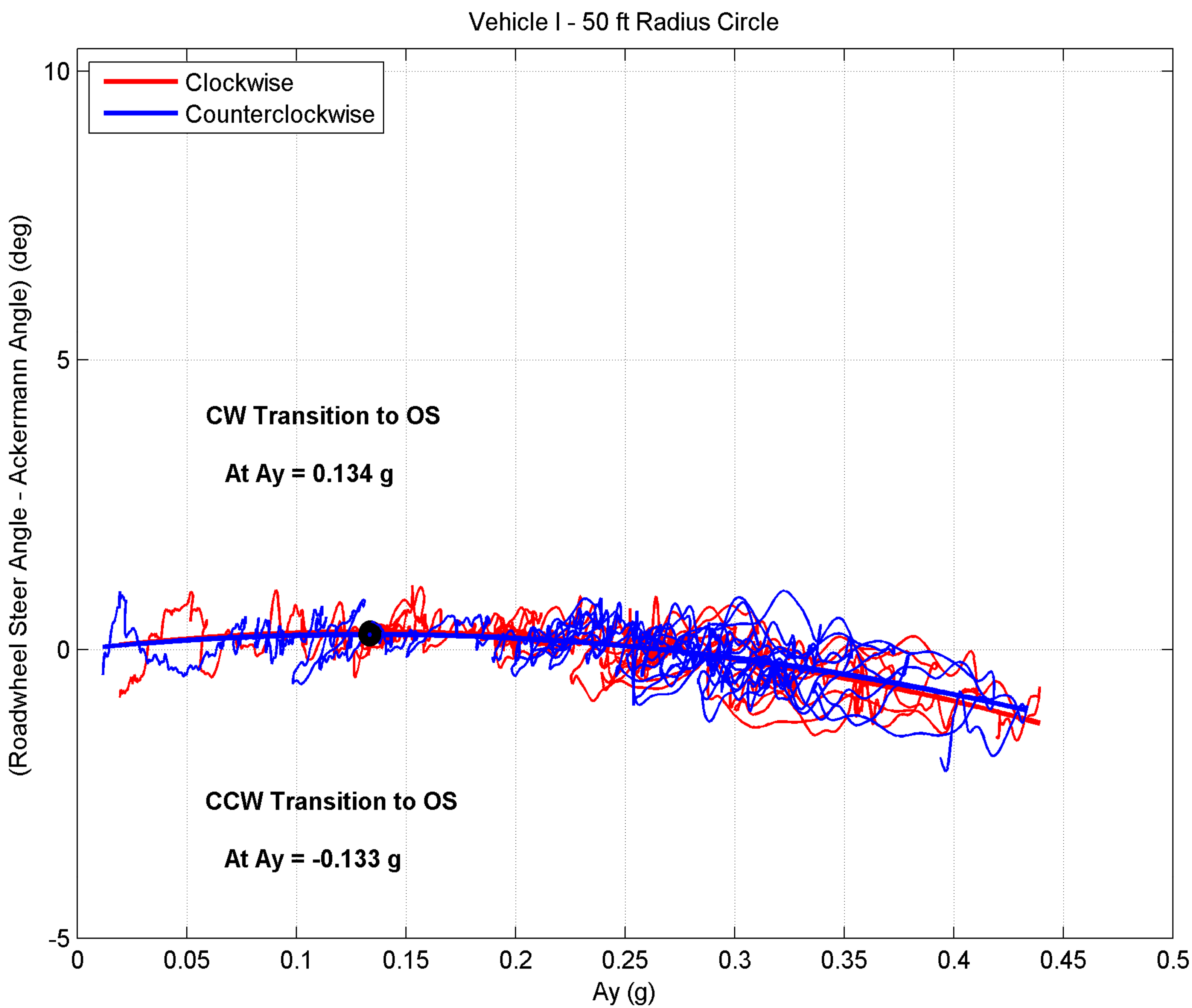


Vehicle H - Steering Ratio
Right Steering Ratio = 1.46 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-50
-40
-30
-20
-10
0
10
20
30
40
50
Left Steering Ratio = 1.361 deg/deg
Left Wheel Steer Angle (deg)
Average Steering Ratio = 1.41 deg/deg
Steering Column Angle (deg)

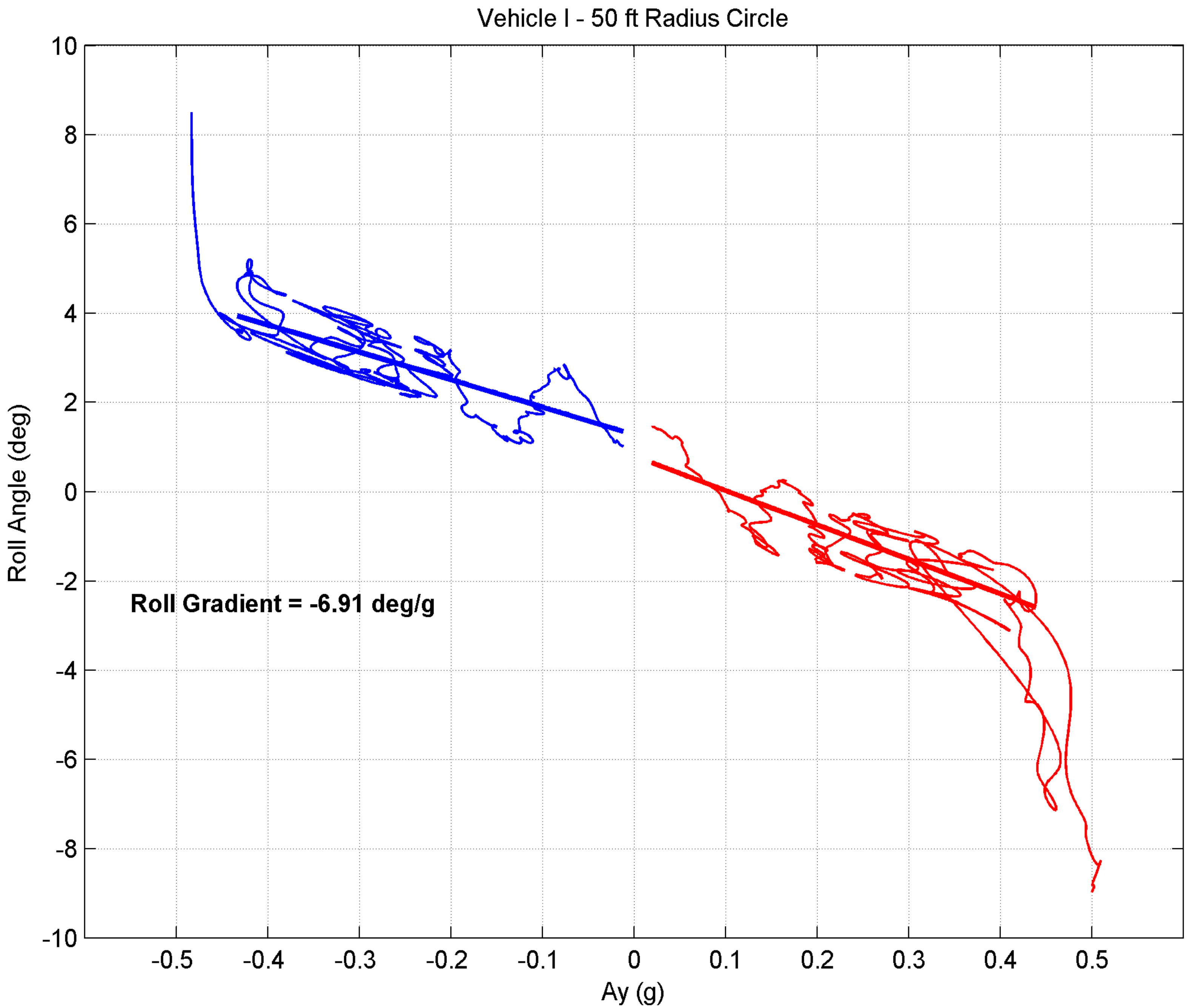


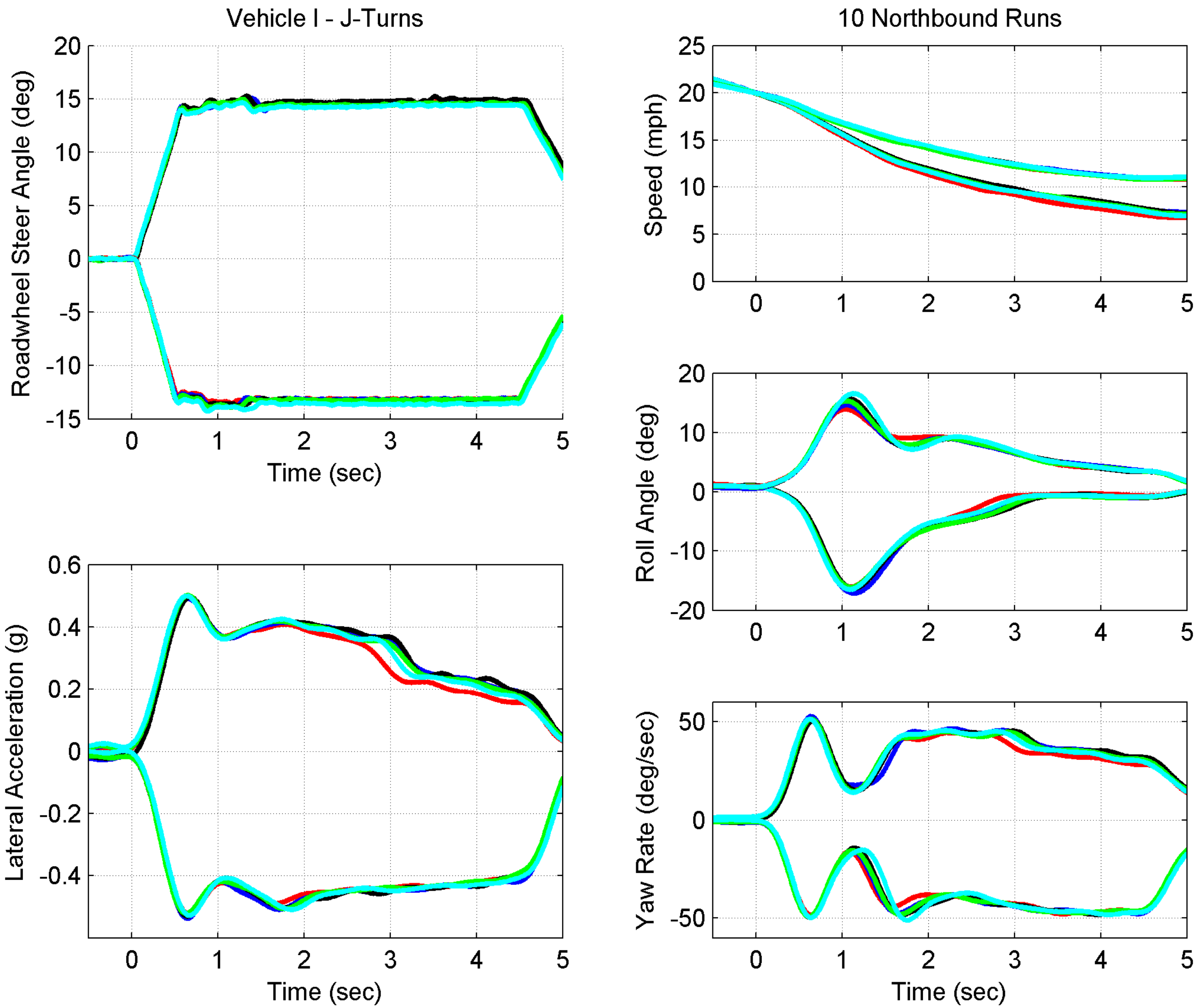
Vehicle I - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle I - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

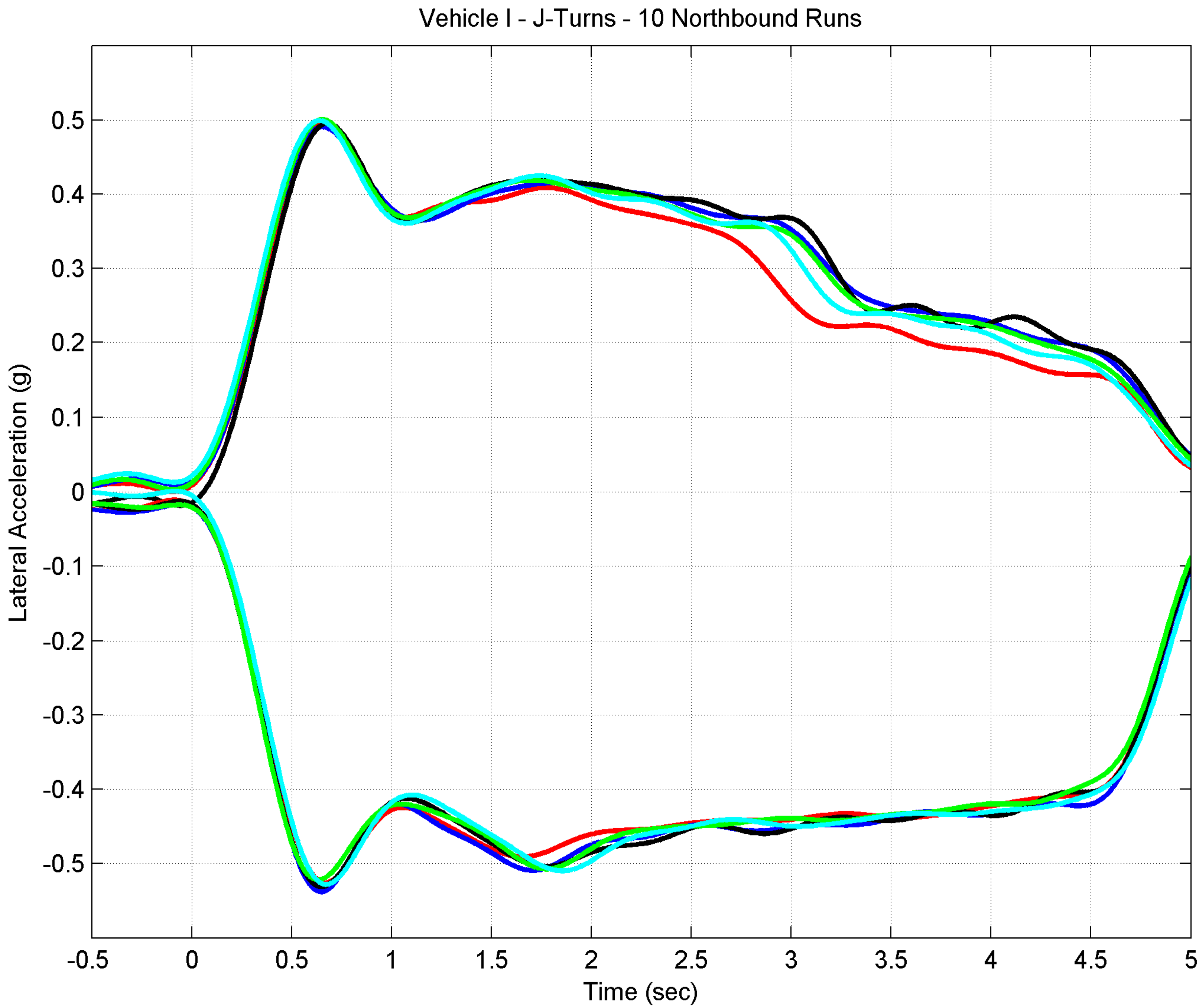


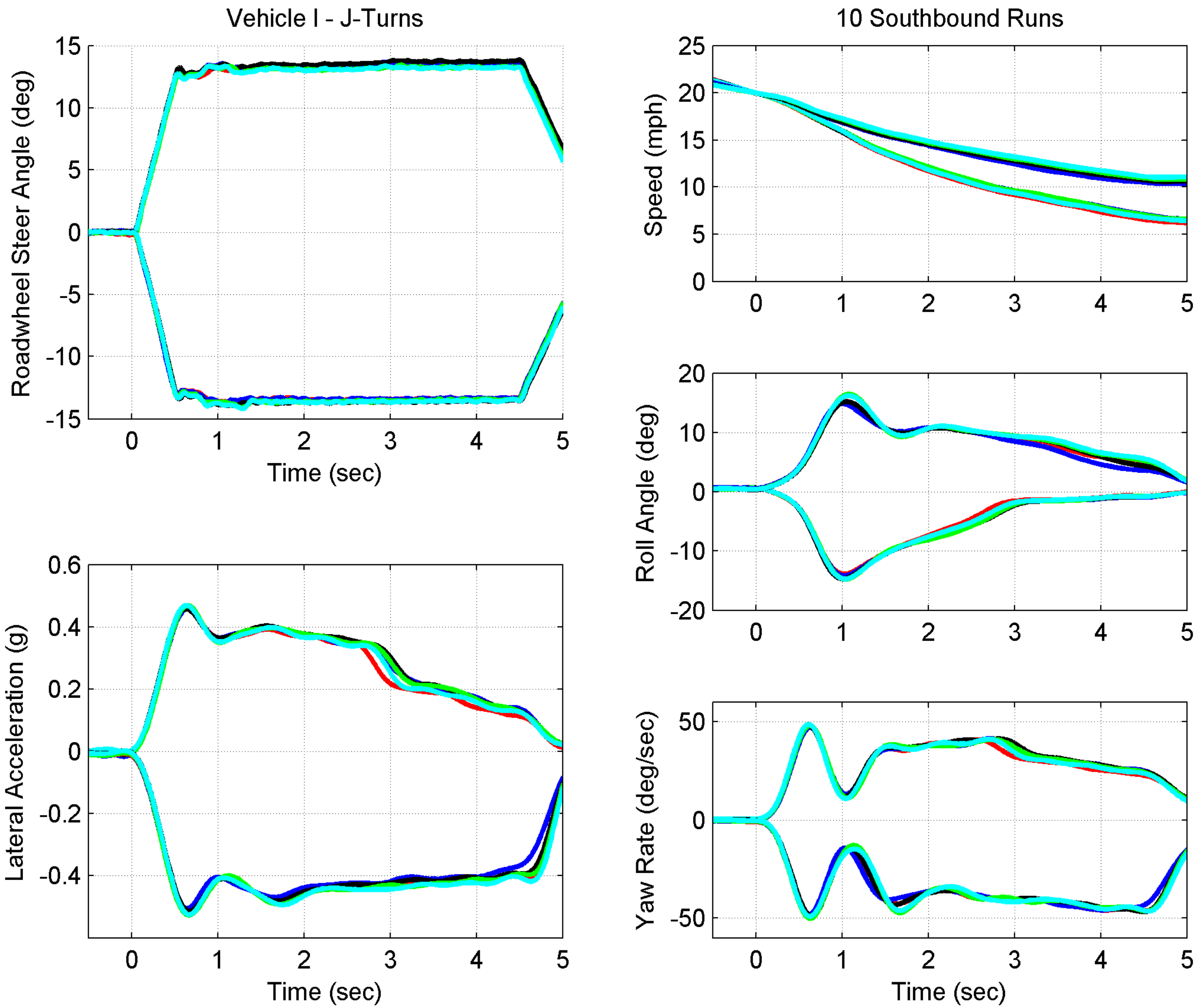
Vehicle I - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.134 g
CCW Transition to OS
At Ay = -0.133 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

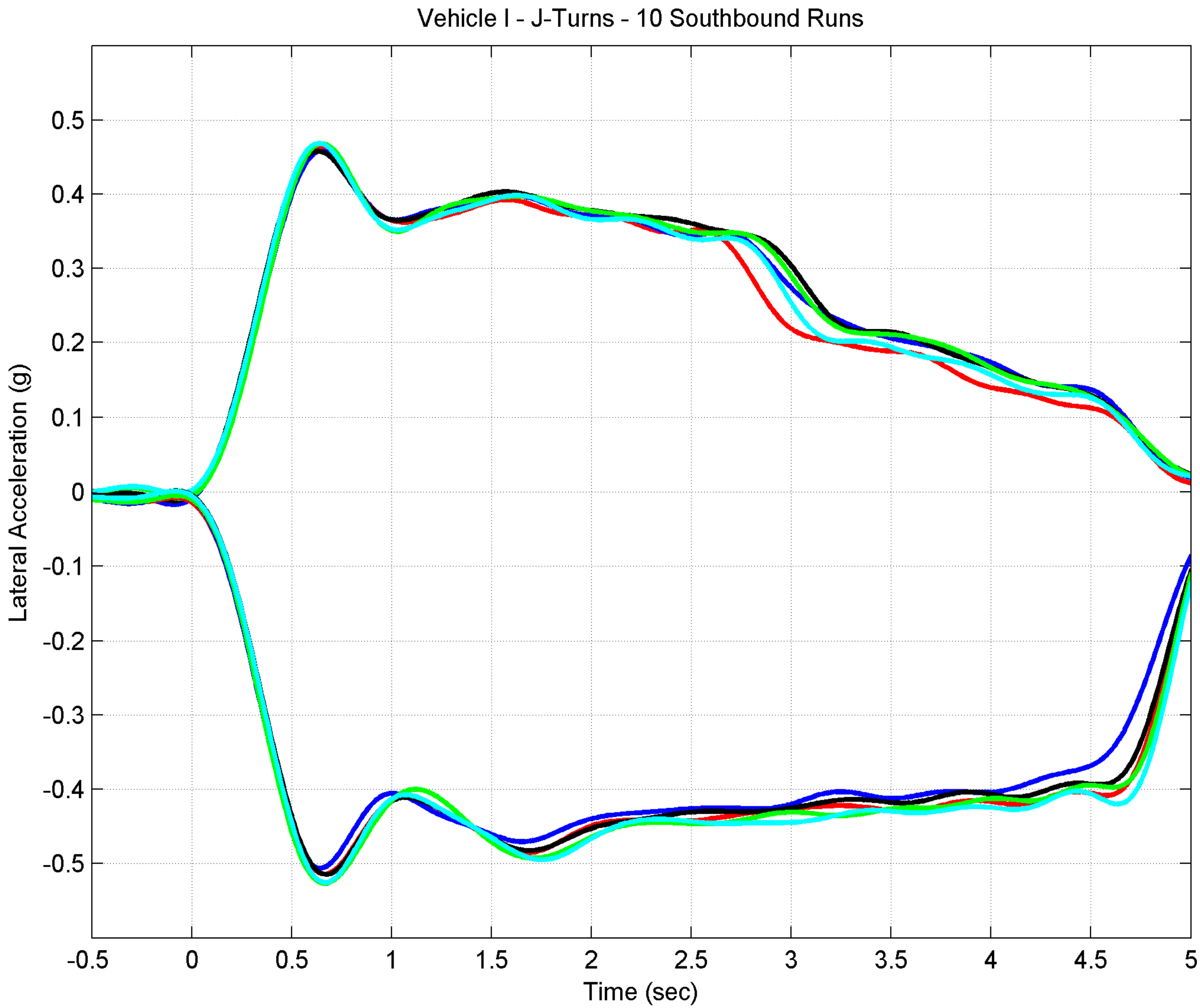

Vehicle I - 50 ft Radius Circle
Roll Gradient = -6.91 deg/g
Roll Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5



Vehicle I - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle I - J-Turns - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle I - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle I - J-Turns - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle I

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.4939	-0.5262
2	0.4908	-0.5383
3	0.4955	-0.5316
4	0.5009	-0.5224
5	0.4991	-0.5285
Mean Value of 5 Runs	0.4960	-0.5294
Standard Deviation of 5 Runs	0.004	0.006

Average of 10 Northbound Runs

0.5127

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.4637	-0.5142
2	0.4580	-0.5063
3	0.4578	-0.5150
4	0.4685	-0.5273
5	0.4685	-0.5260
Mean Value of 5 Runs	0.4633	-0.5178
Standard Deviation of 5 Runs	0.005	0.009

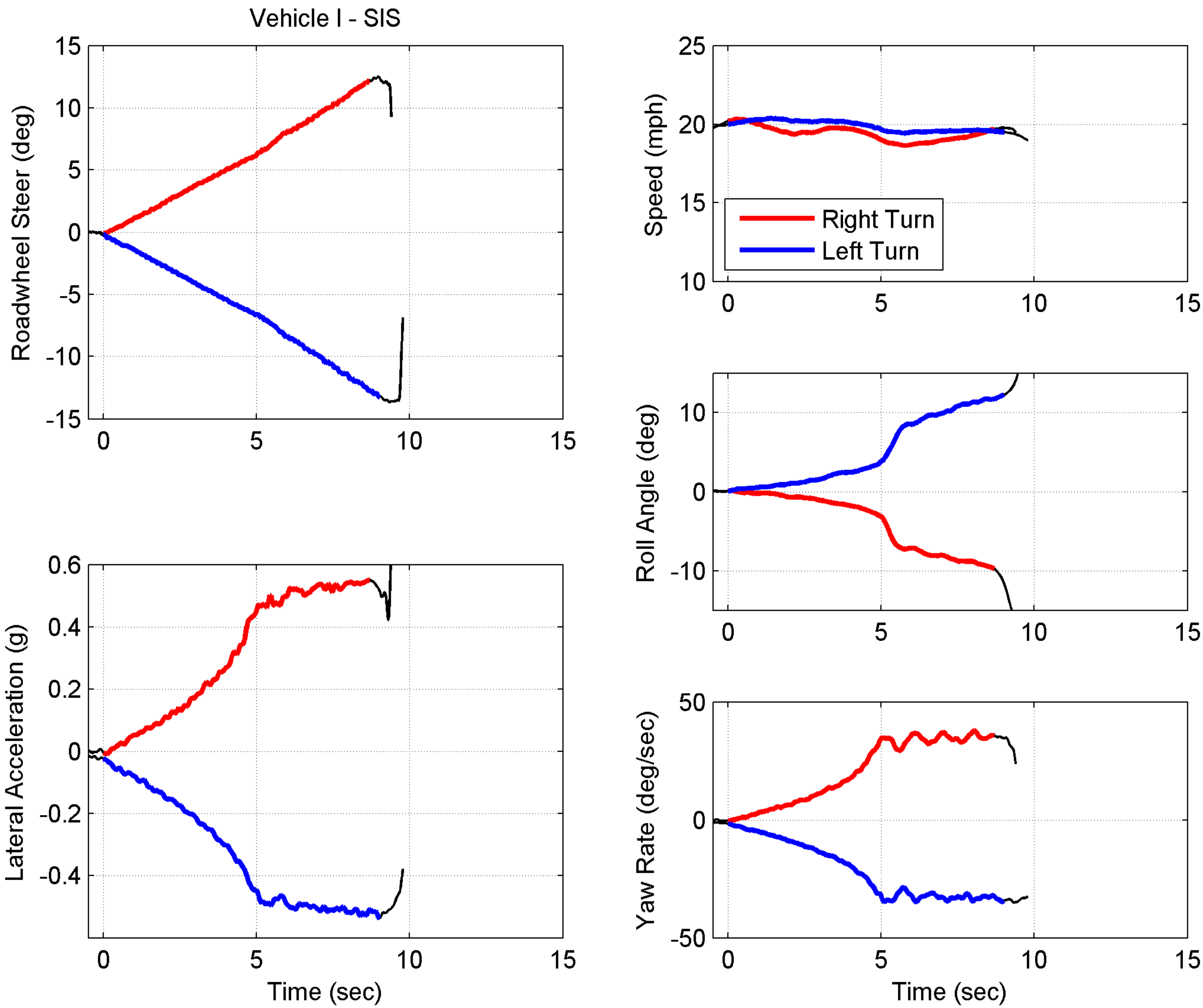
Average of 10 Southbound Runs

0.4905

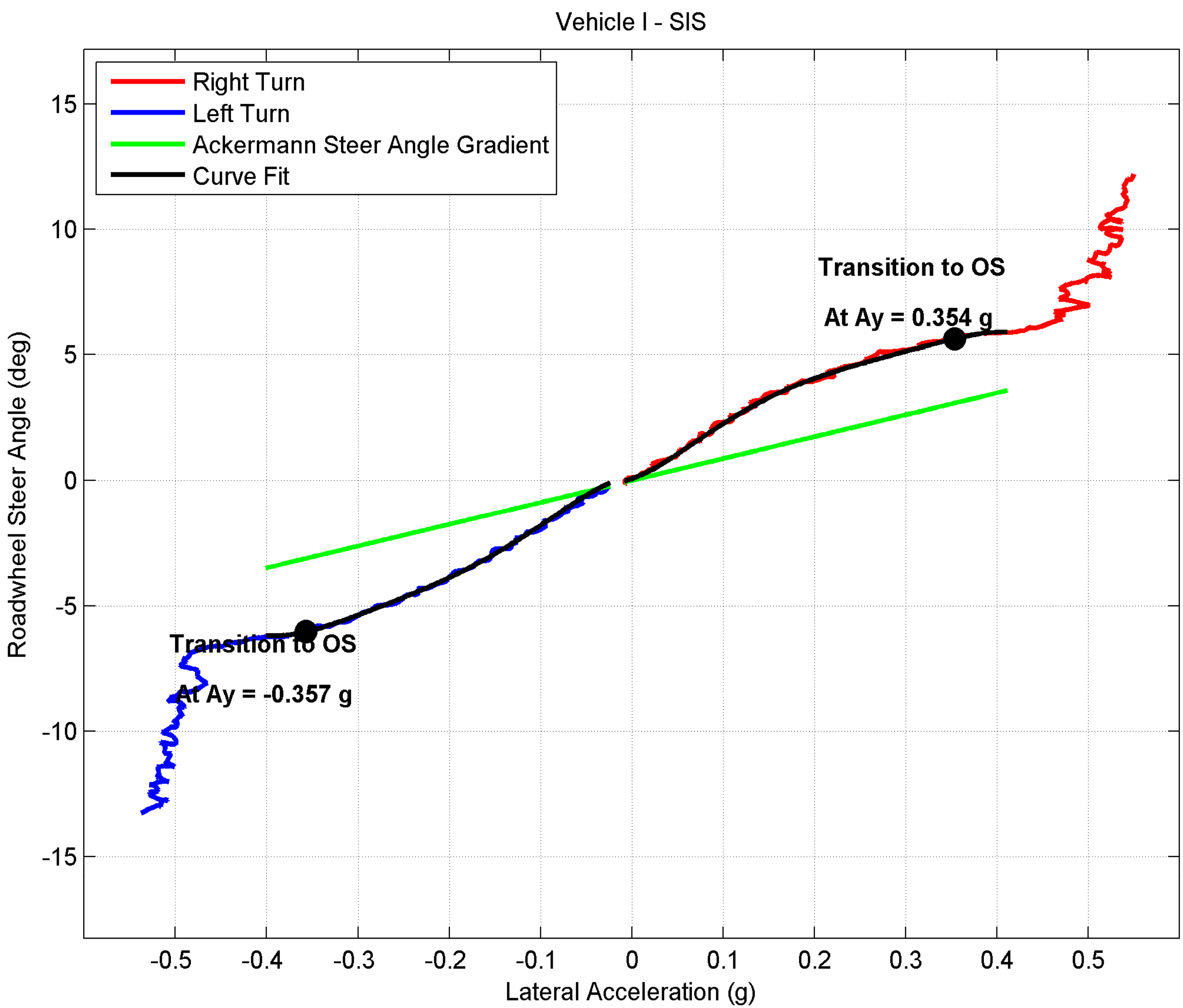
Average of All 20 Runs

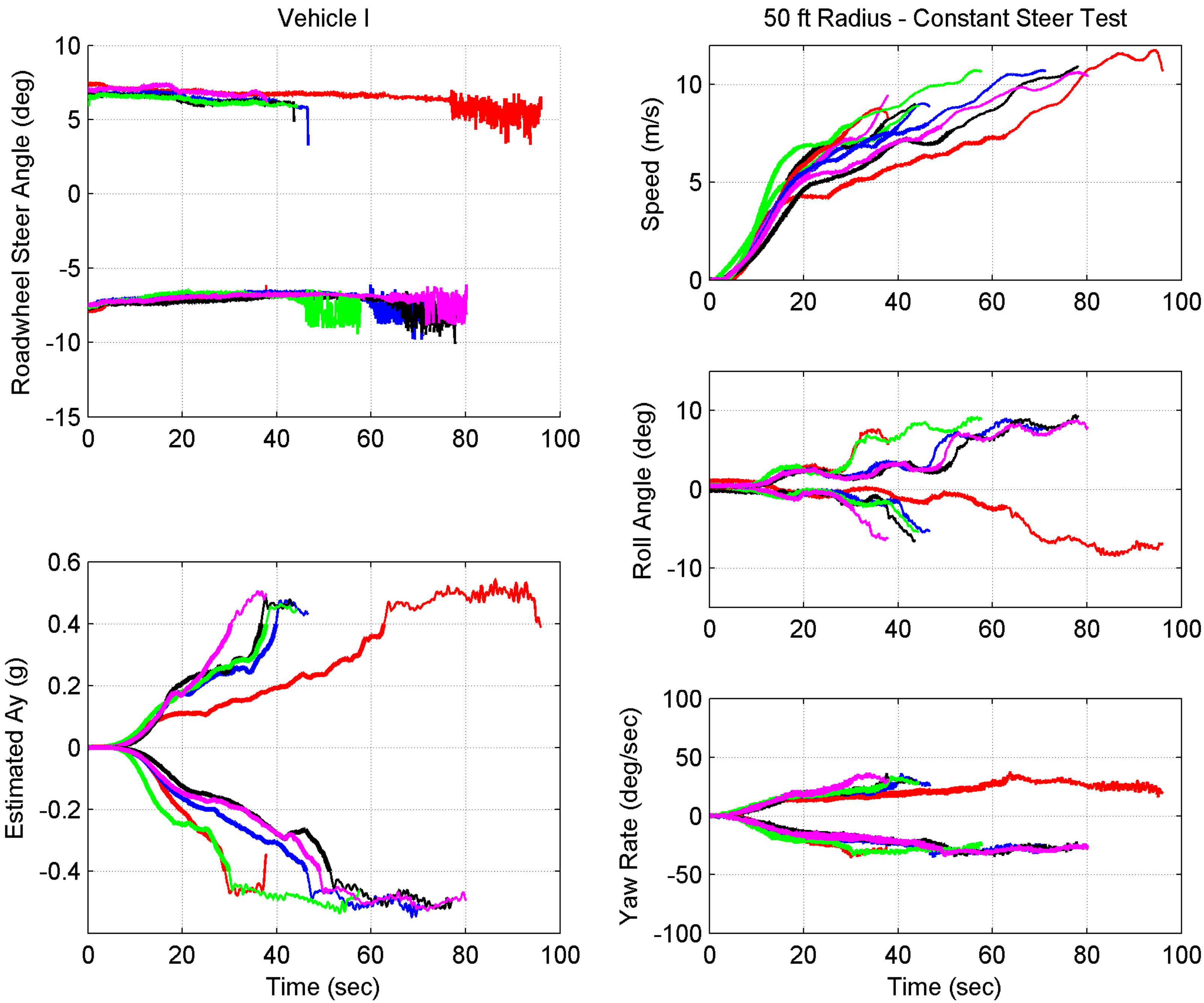
0.502

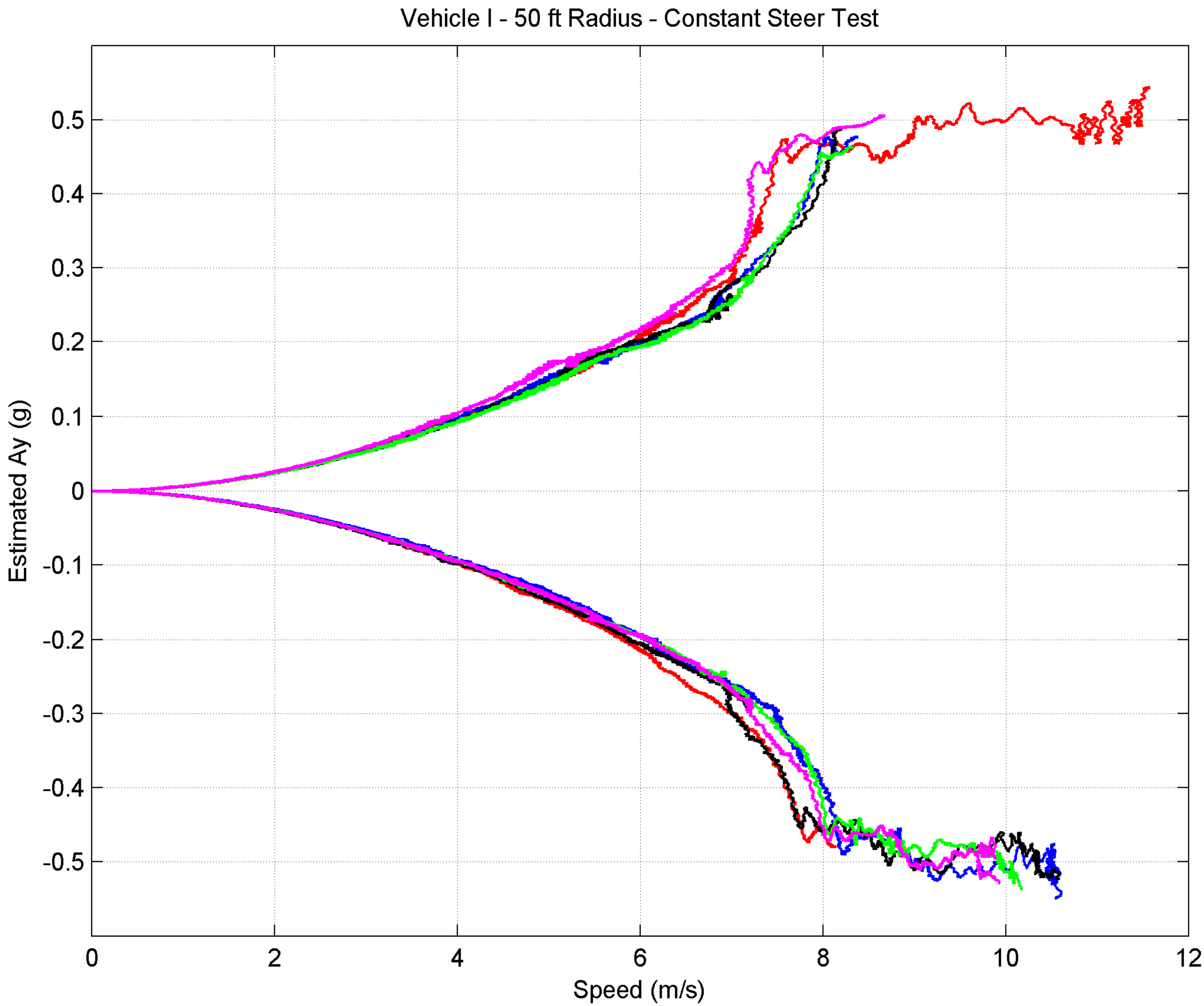
Threshold Ay



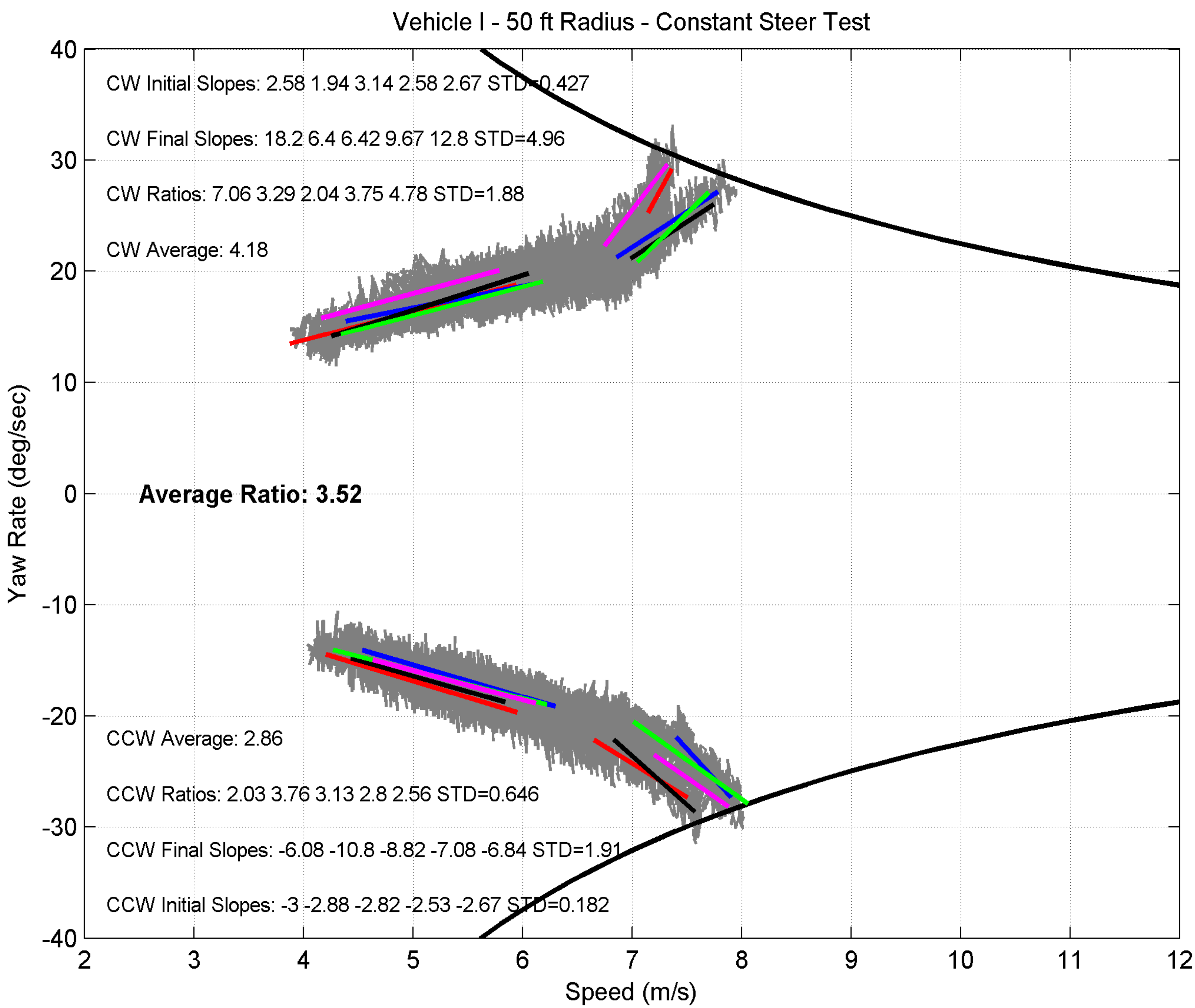
Vehicle I - SIS
Roadwheel Steer (deg)
15
10
5
0
-5
-10
-15
0
5
10
15
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Time (sec)
Speed (mph)
25
20
15
10
Right Turn
Left Turn
Roll Angle (deg)
Yaw Rate (deg/sec)
50
-50

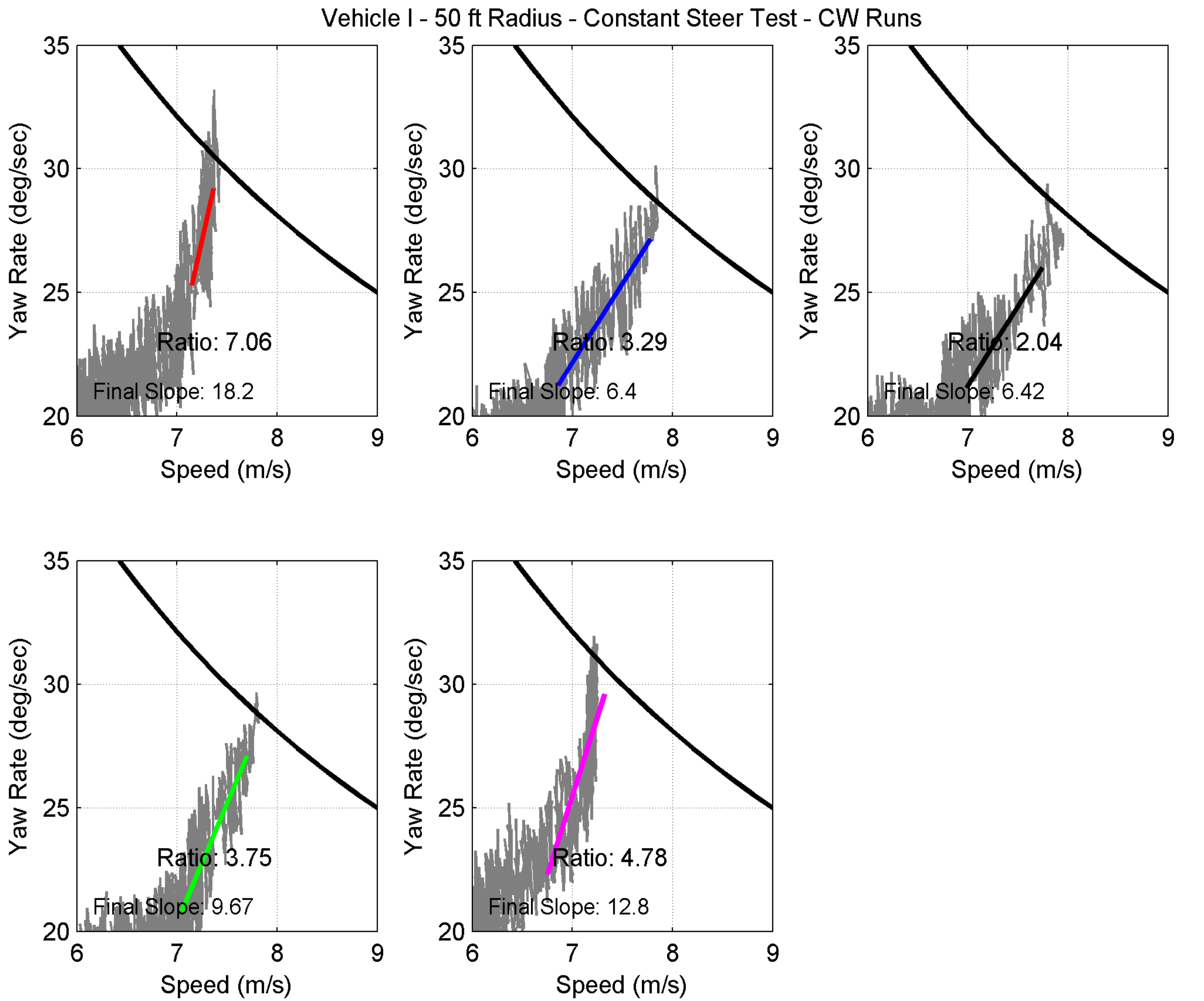

Vehicle I - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to OS
At Ay = 0.354 g
Transition to OS
At Ay = -0.357 g
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5


Vehicle I
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
10
5
0
-5
-10
-15
0
20
40
60
80
100
0.6
0.4
0.2
0
-0.2
-0.4
-50
-100

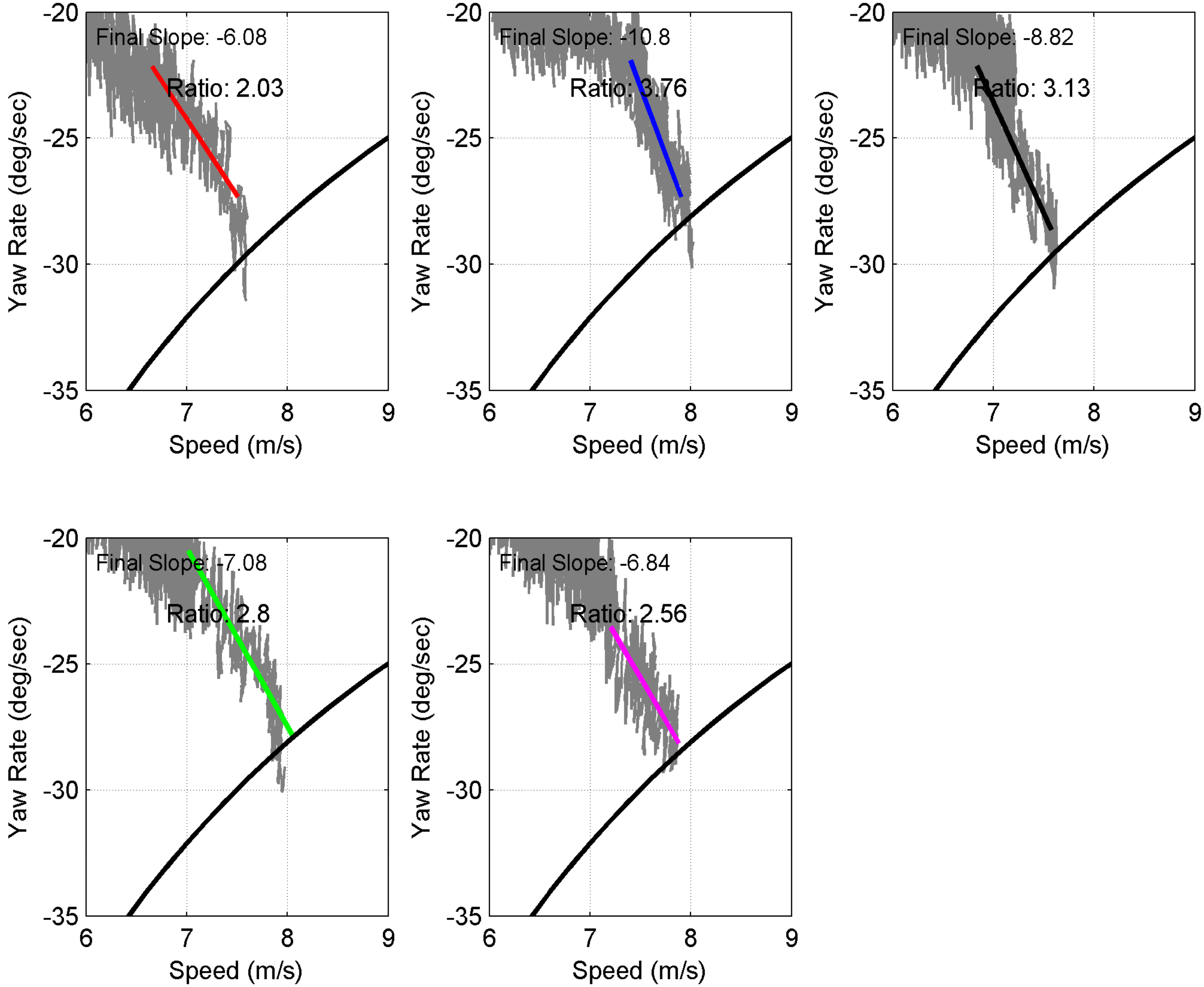


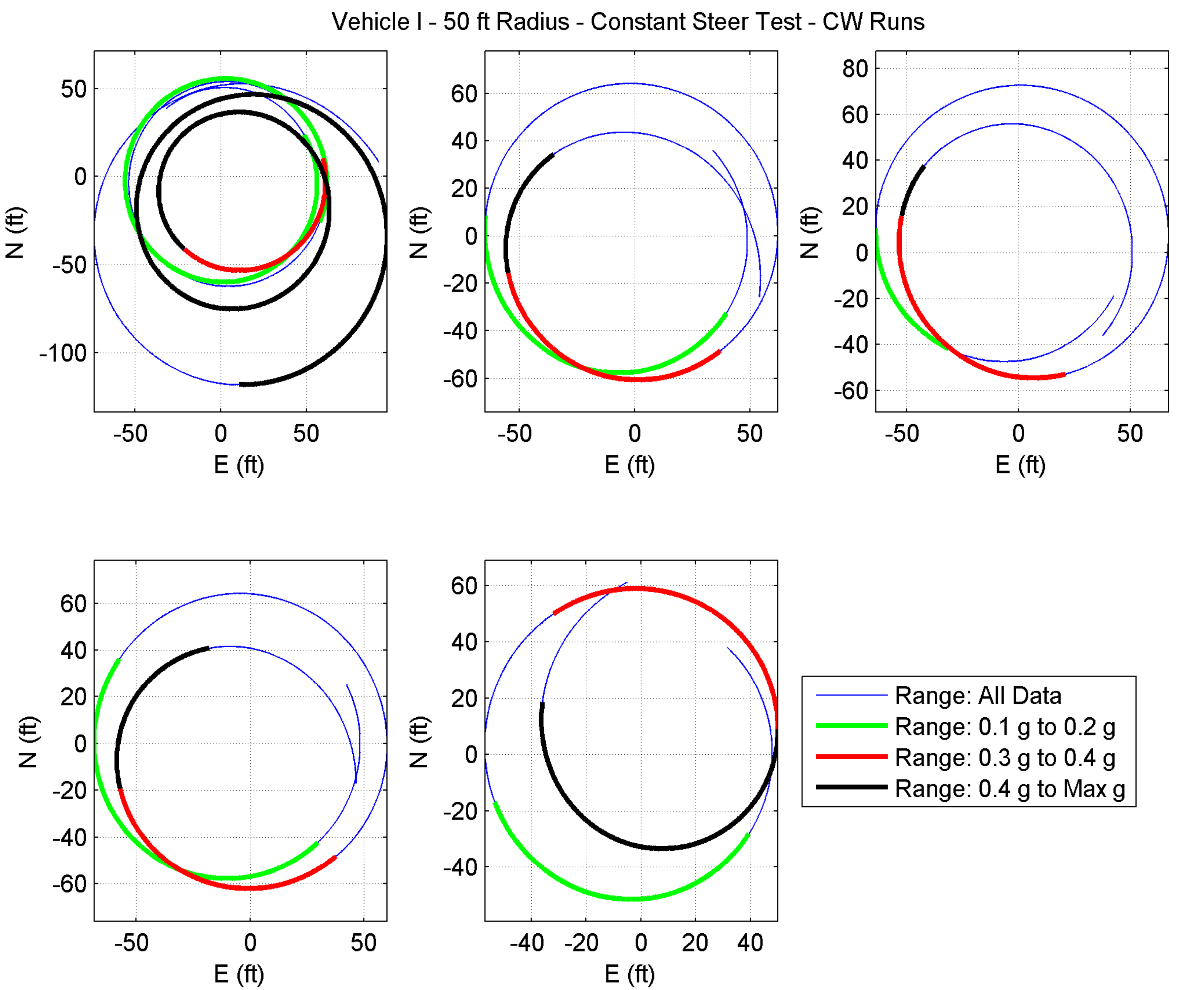
Vehicle I - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
2
4
6
8
10
12


Vehicle I - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 2.58 1.94 3.14 2.58 2.67 STD=0.427
CW Final Slopes: 18.2 6.4 6.42 9.67 12.8 STD=4.96
CW Ratios: 7.06 3.29 2.04 3.75 4.78 STD=1.88
CW Average: 4.18
Average Ratio: 3.52
CCW Average: 2.86
CCW Ratios: 2.03 3.76 3.13 2.8 2.56 STD=0.646
CCW Final Slopes: -6.08 -10.8 -8.82 -7.08 -6.84 STD=1.91
CCW Initial Slopes: -3 -2.88 -2.82 -2.53 -2.67 STD=0.182
Yaw Rate (deg/sec)
Speed (m/s)
40
30
20
10
0
-10
-20
-30
-40
2
3
4
5
6
7
8
9
10
11
12


Vehicle I - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 7.06
Final Slope: 18.2
Ratio: 3.29
Final Slope: 6.4
Ratio: 2.04
Final Slope: 6.42
Ratio: 3.75
Final Slope: 9.67
Ratio: 4.78
Final Slope: 12.8

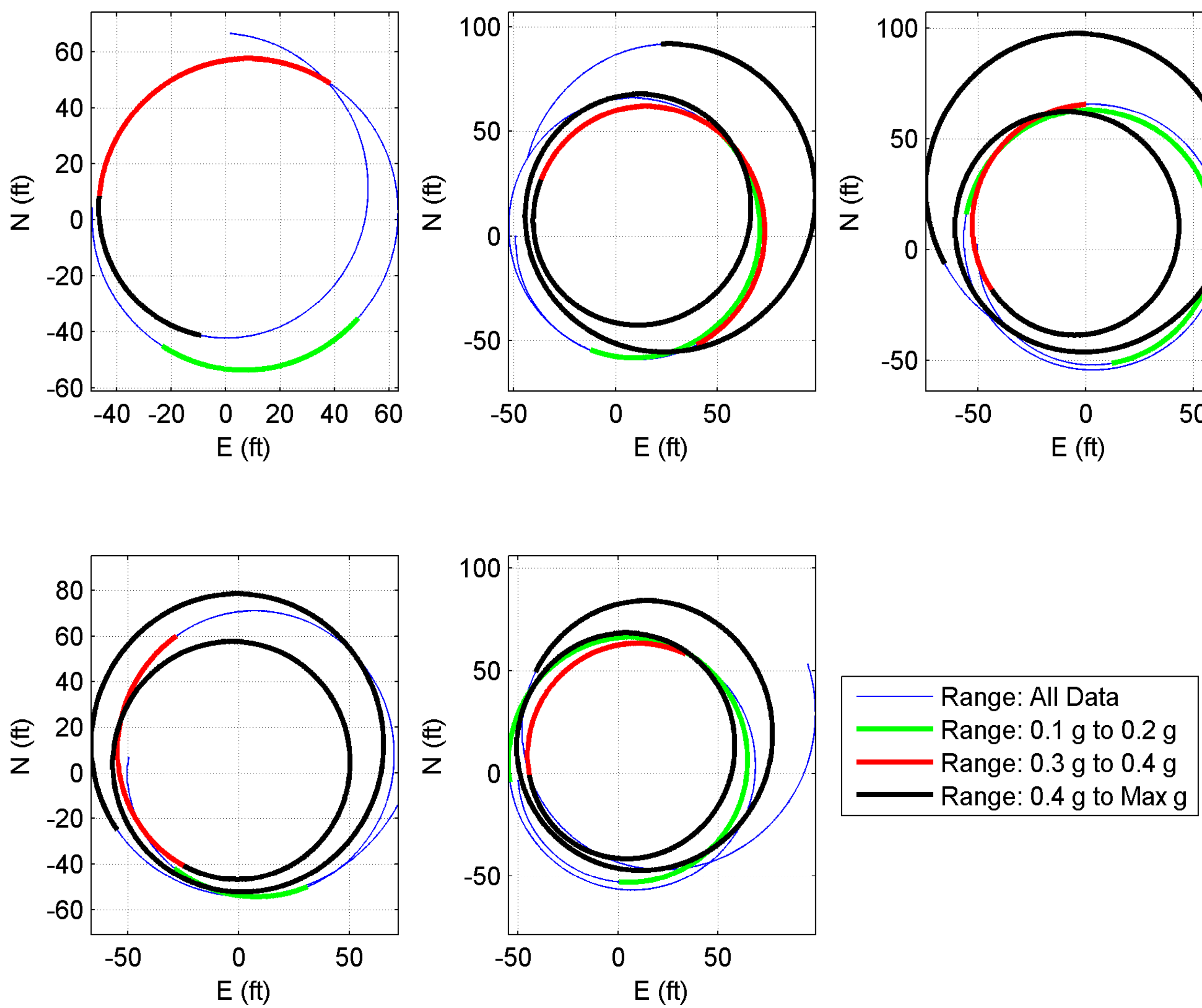
Vehicle I - 50 ft Radius - Constant Steer Test - CCW Runs

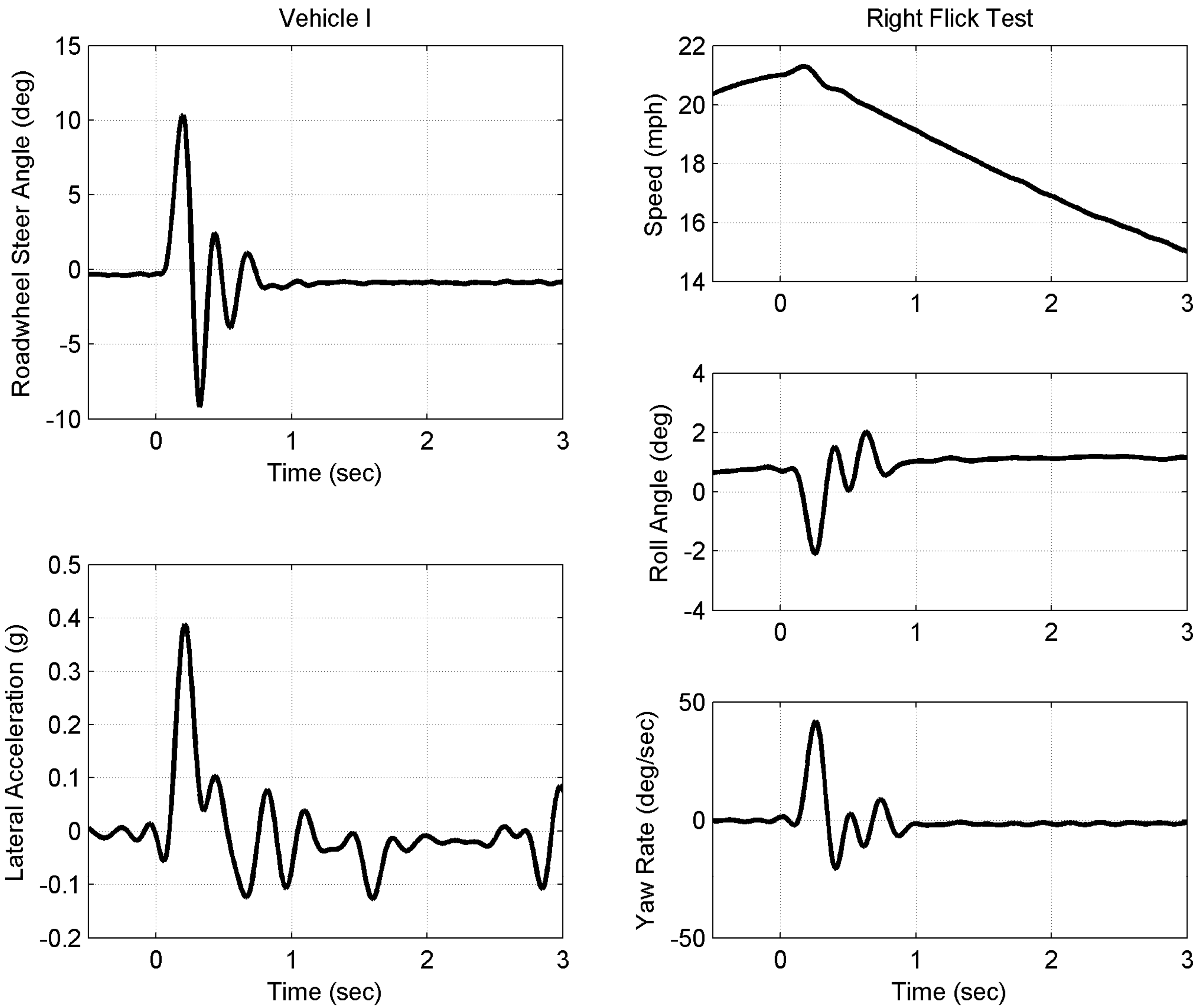


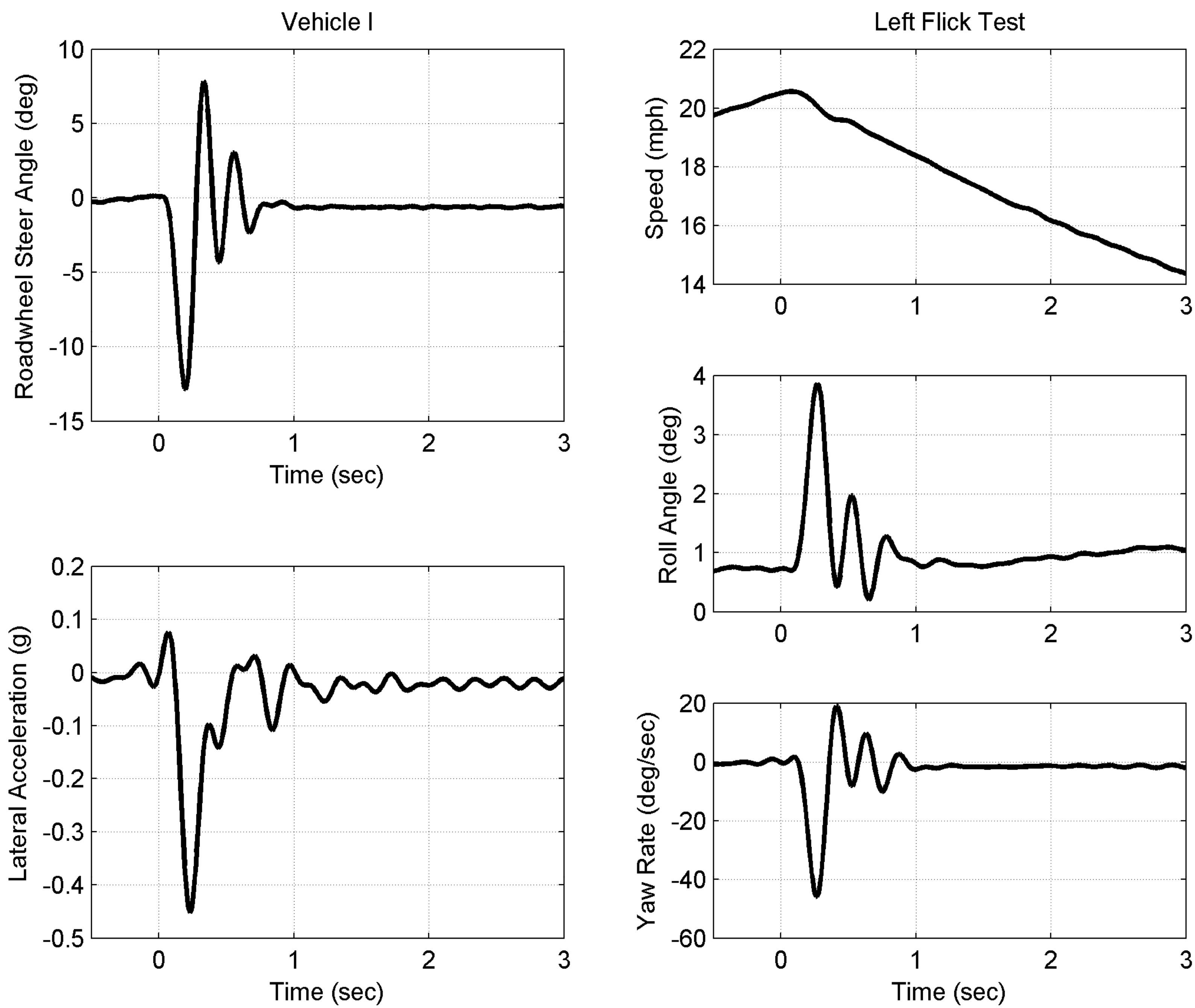


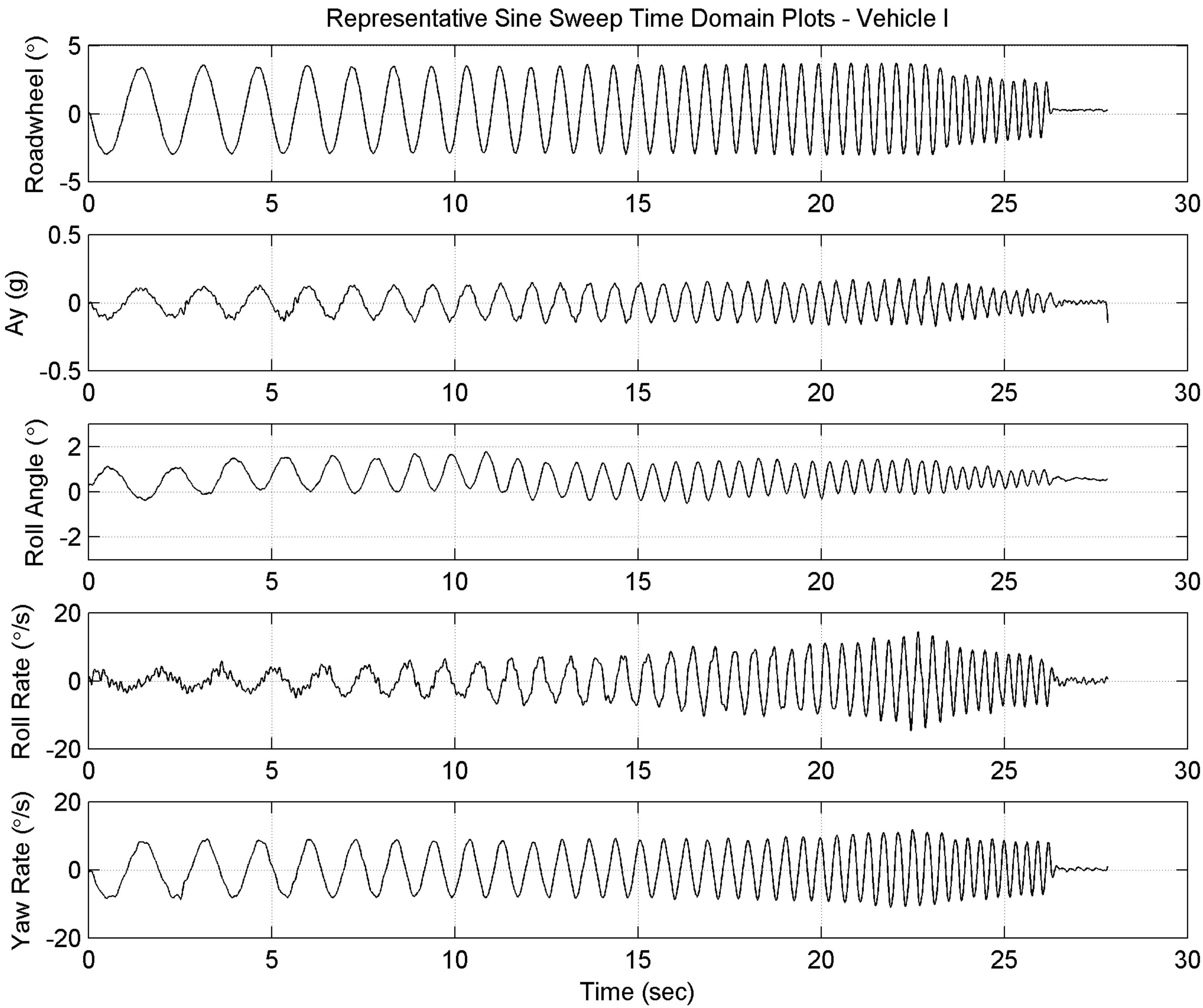
Vehicle I - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

Vehicle I - 50 ft Radius - Constant Steer Test - CCW Runs

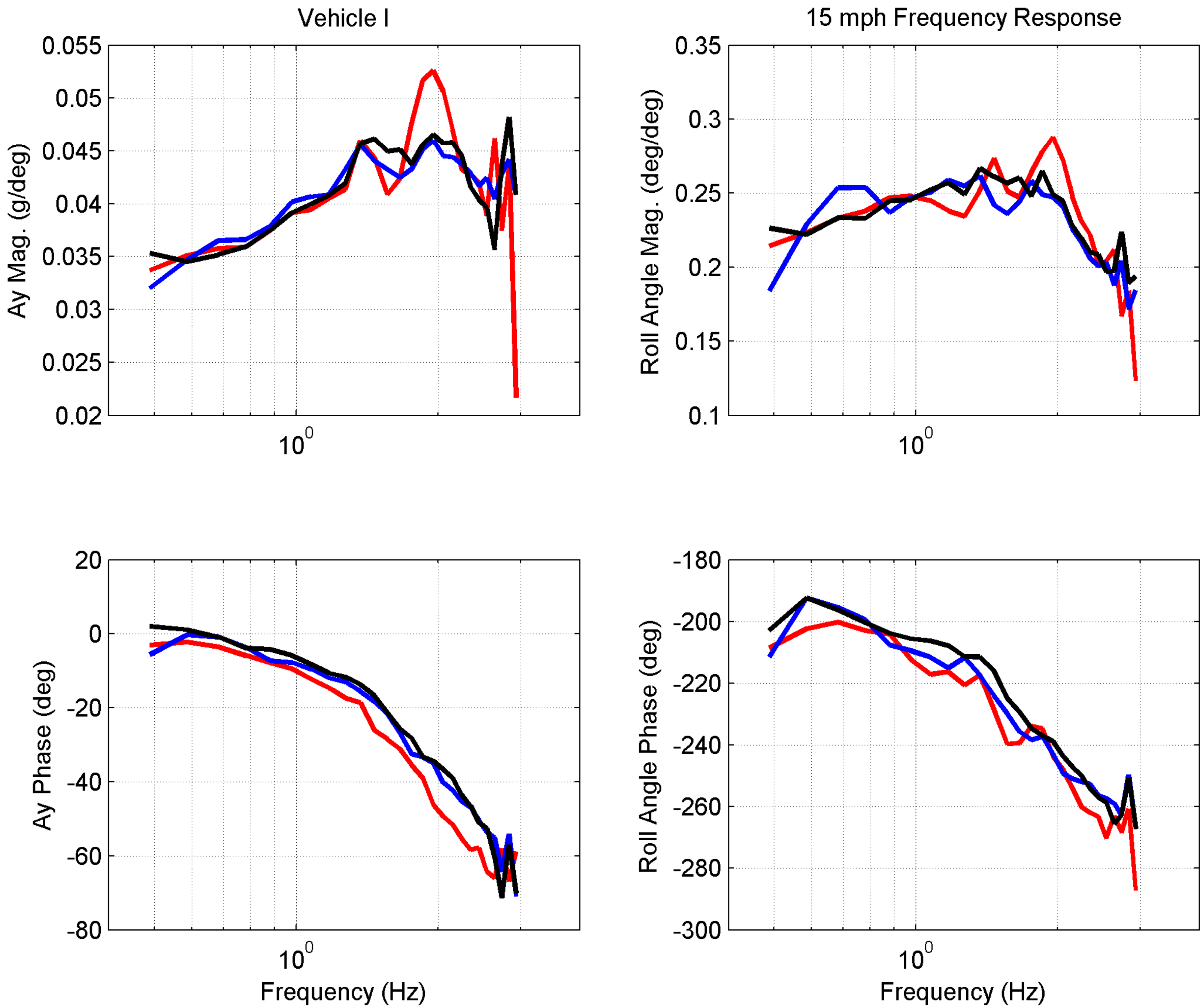


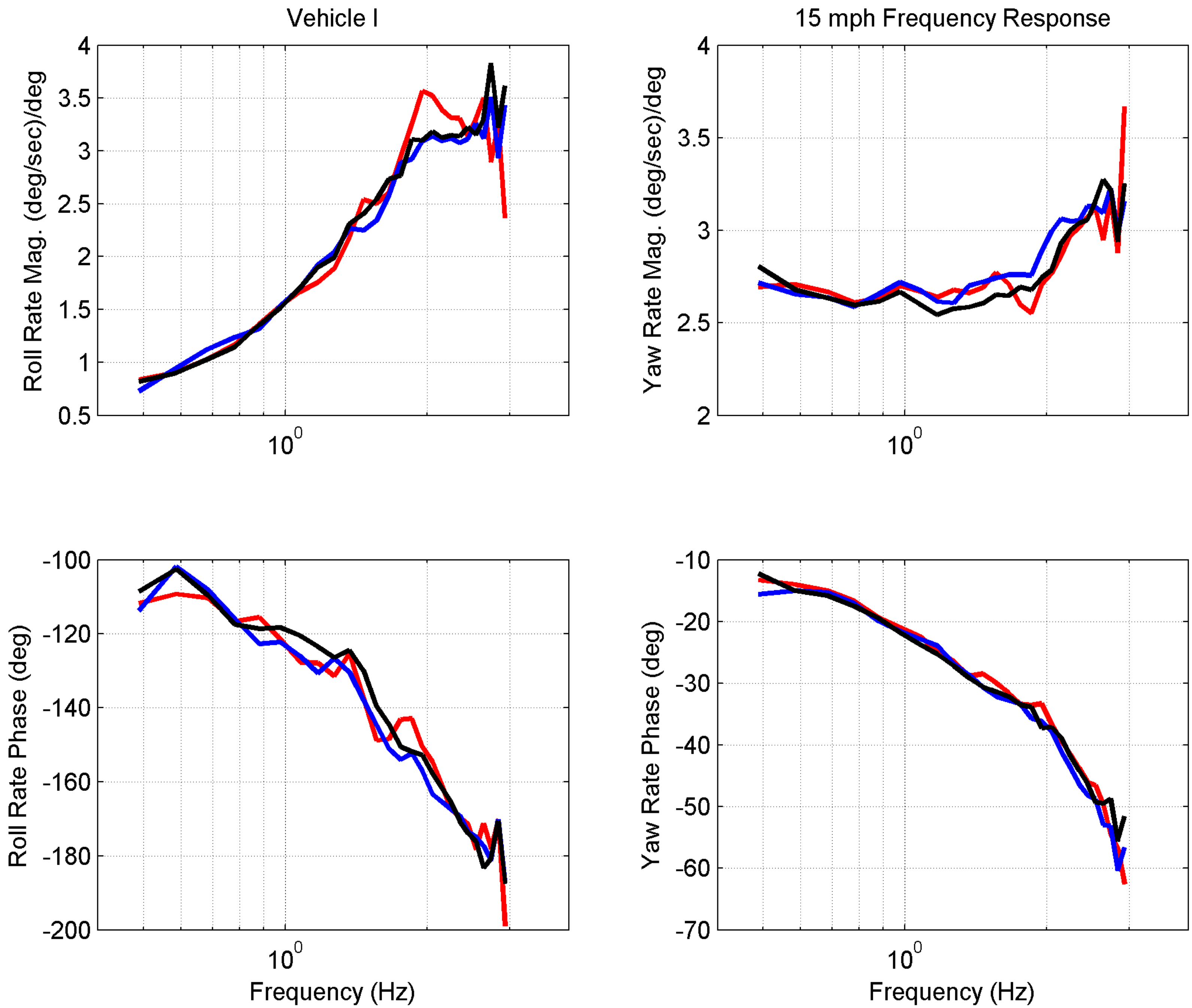

Vehicle I
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)


Vehicle I
Left Flick Test
Roadwheel Steer Angle (deg)
10
5
0
-5
-10
-15
0
1
2
3
Time (sec)
Speed (mph)
22
20
18
16
14
Roll Angle (deg)
4
3
2
1
0
Lateral Acceleration (g)
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Yaw Rate (deg/sec)
20
0
-20
-40
-60
Time (sec)
Time (sec)

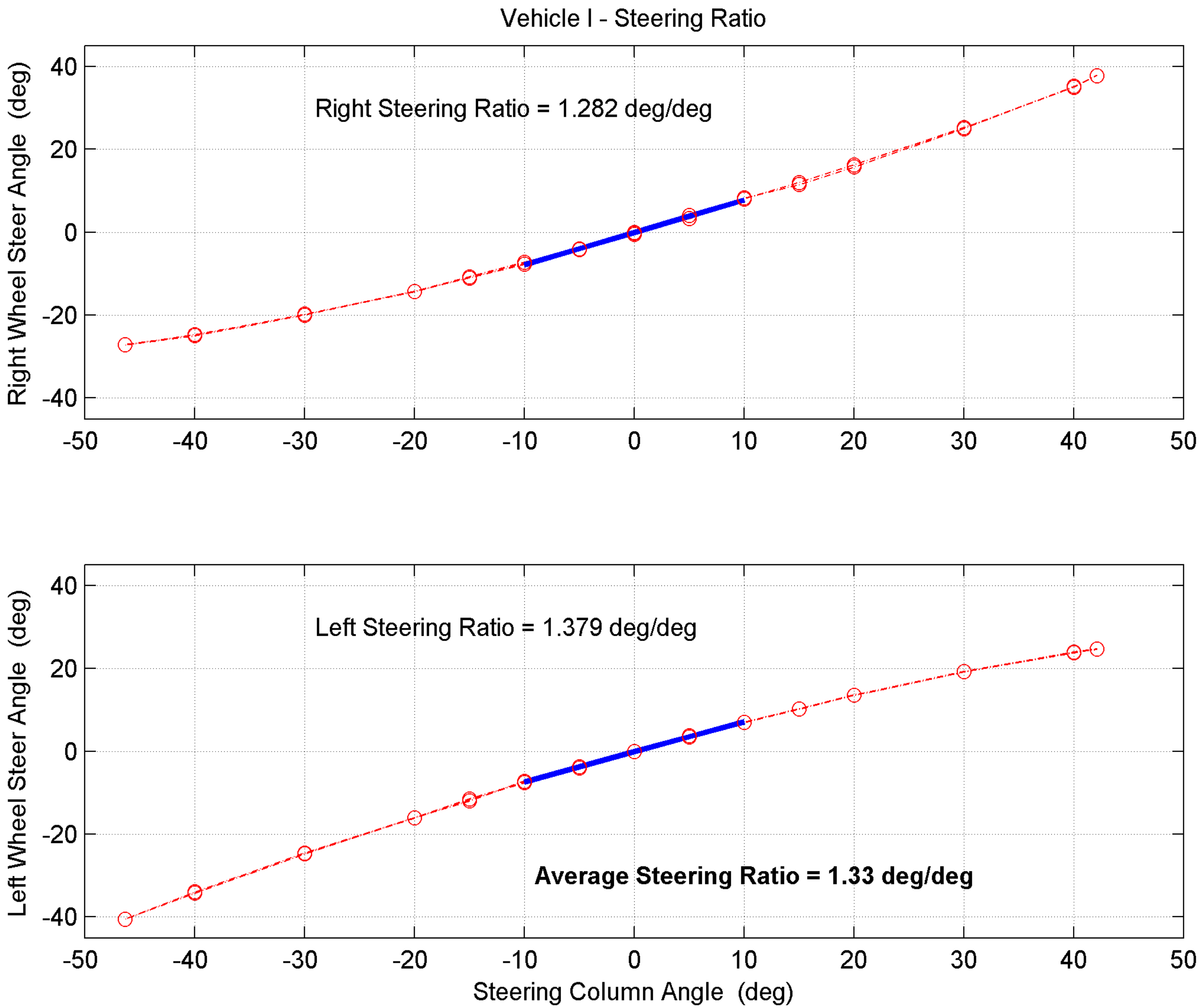


Representative Sine Sweep Time Domain Plots - Vehicle I
Roadwheel (°)
5
0
-5
Ay (g)
0.5
0
-0.5
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
20
0
-20
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)

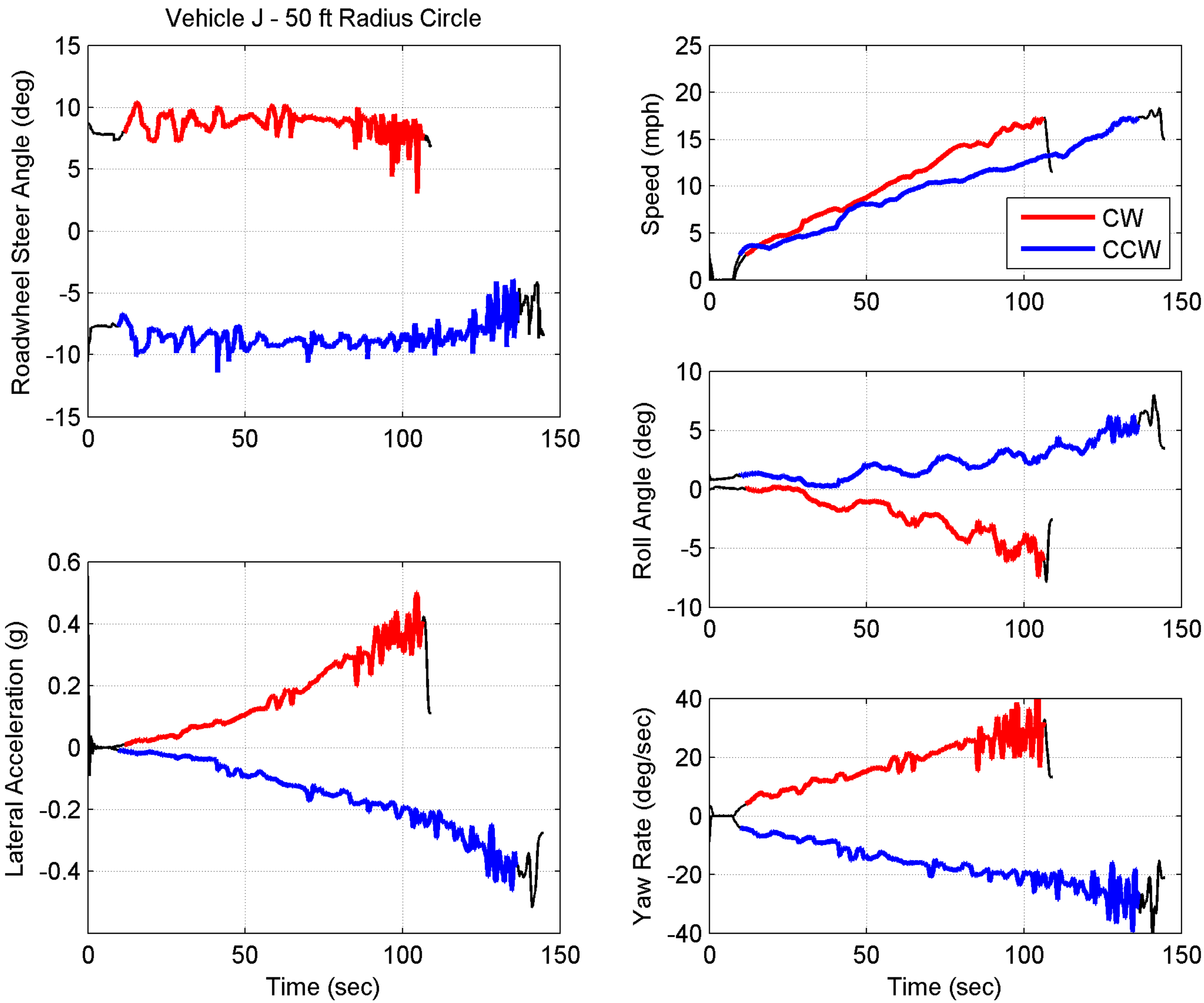

Vehicle I
15 mph Frequency Response
Ay Mag. (g/deg)
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
Roll Angle Mag. (deg/deg)
0.35
0.3
0.25
0.2
0.15
0.1
10^0
Ay Phase (deg)
20
0
-20
-40
-60
-80
Roll Angle Phase (deg)
-180
-200
-220
-240
-260
-280
-300
Frequency (Hz)
Frequency (Hz)



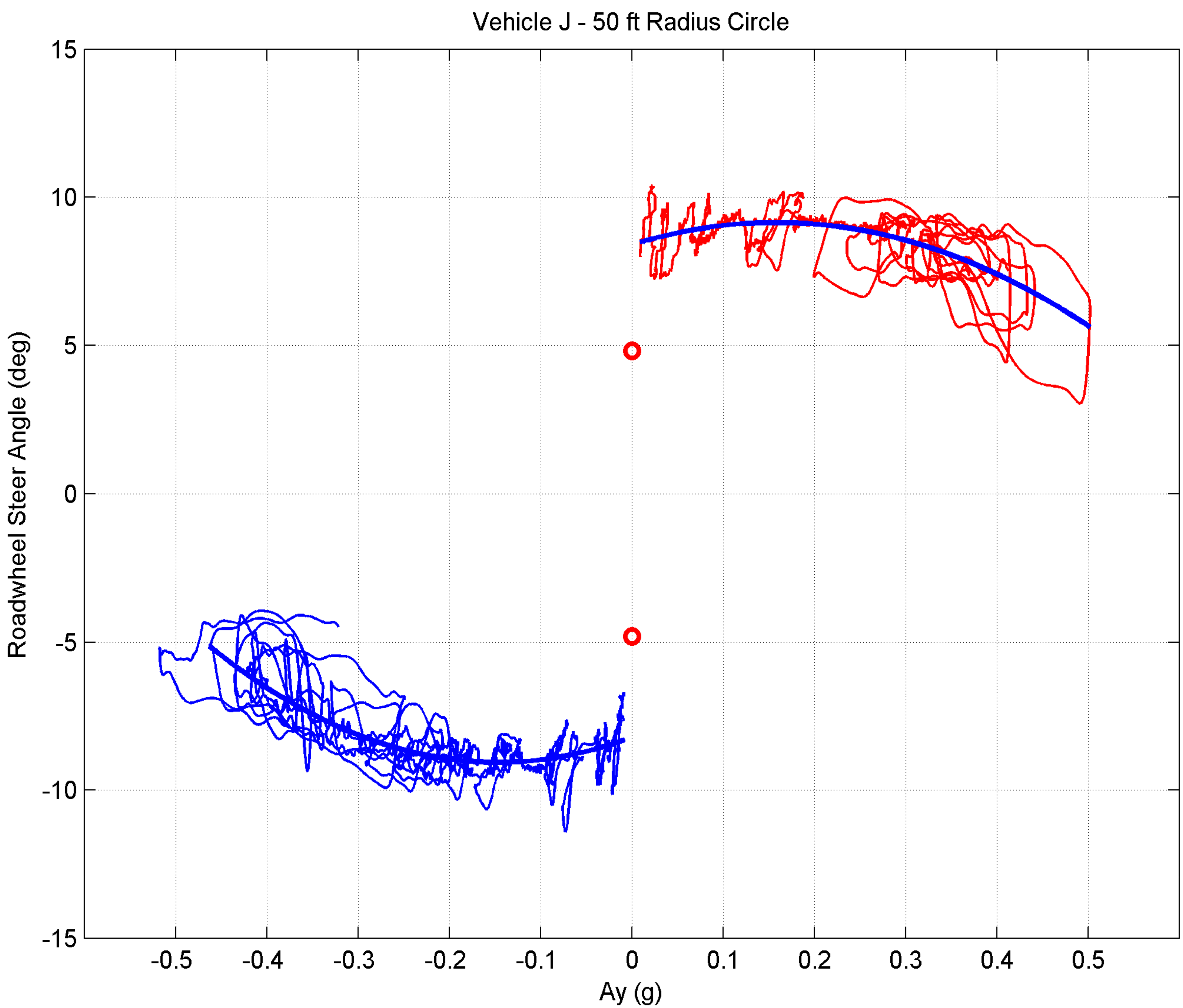
Vehicle I
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
4
3.5
3
2.5
2
1.5
1
0.5
-100
-120
-140
-160
-180
-200
-10
-20
-30
-40
-50
-60
-70
10^0
Frequency (Hz)

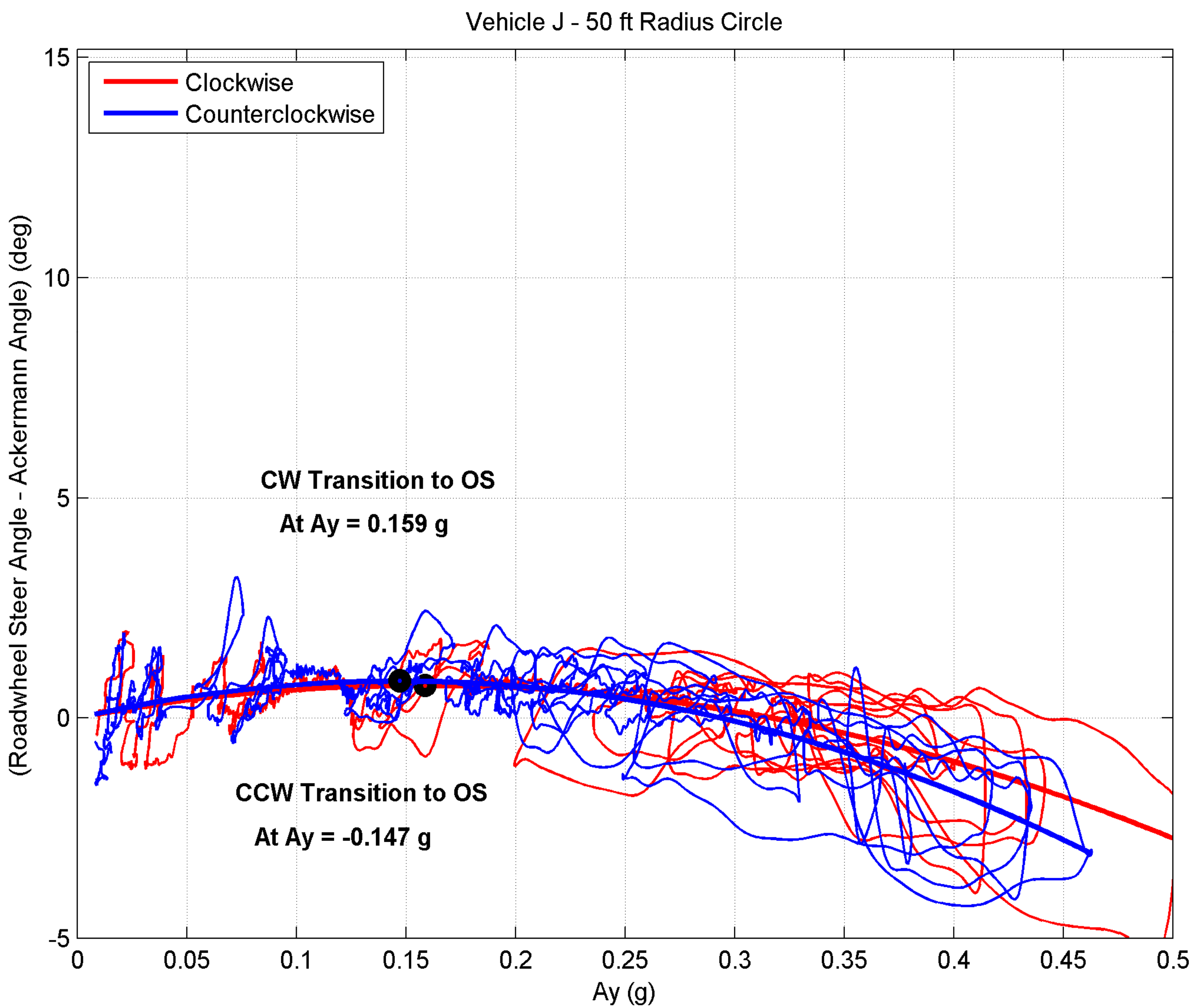


Vehicle I - Steering Ratio
Right Steering Ratio = 1.282 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-50
-40
-30
-20
-10
0
10
20
30
40
50
Left Steering Ratio = 1.379 deg/deg
Average Steering Ratio = 1.33 deg/deg
Left Wheel Steer Angle (deg)
Steering Column Angle (deg)

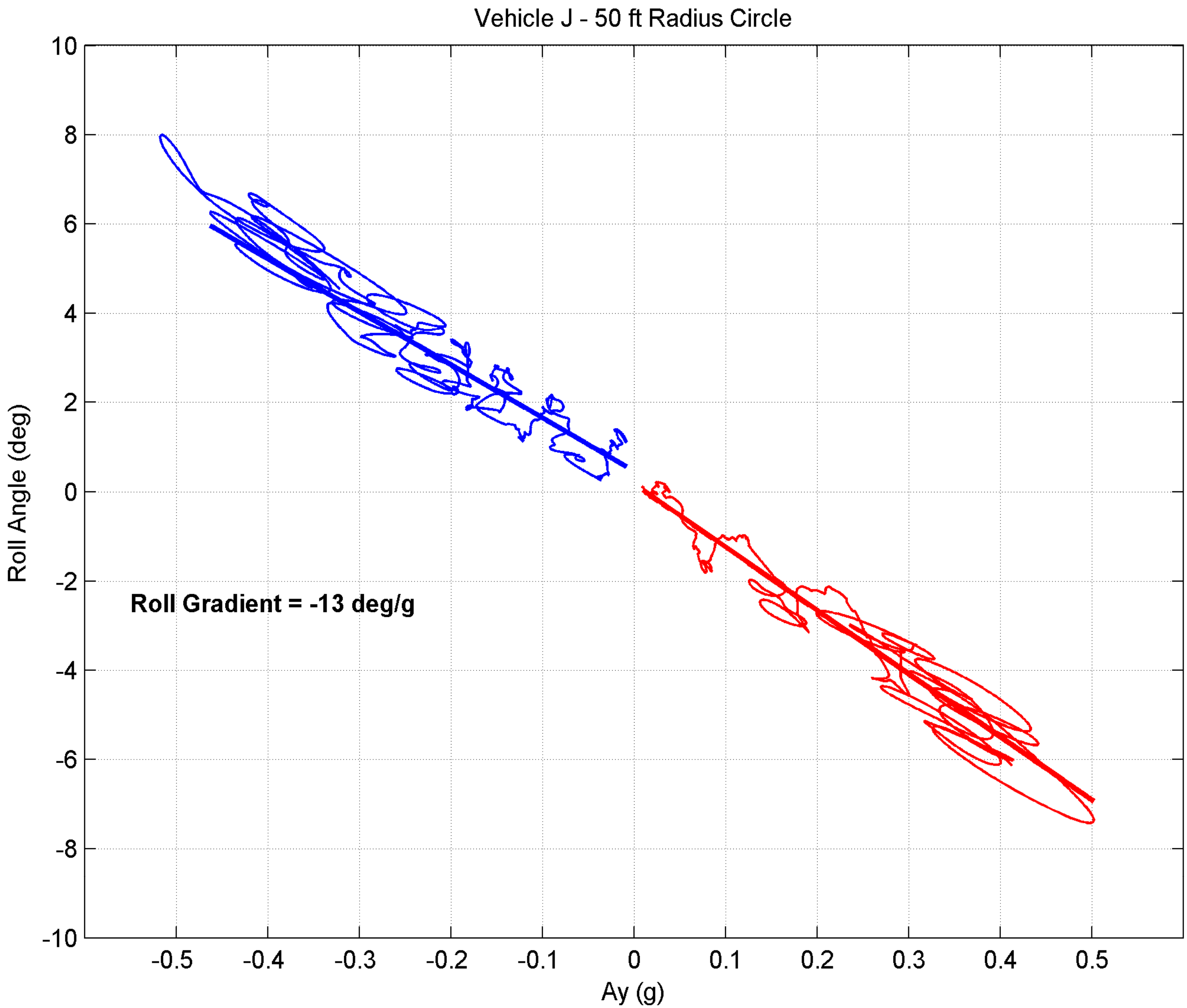


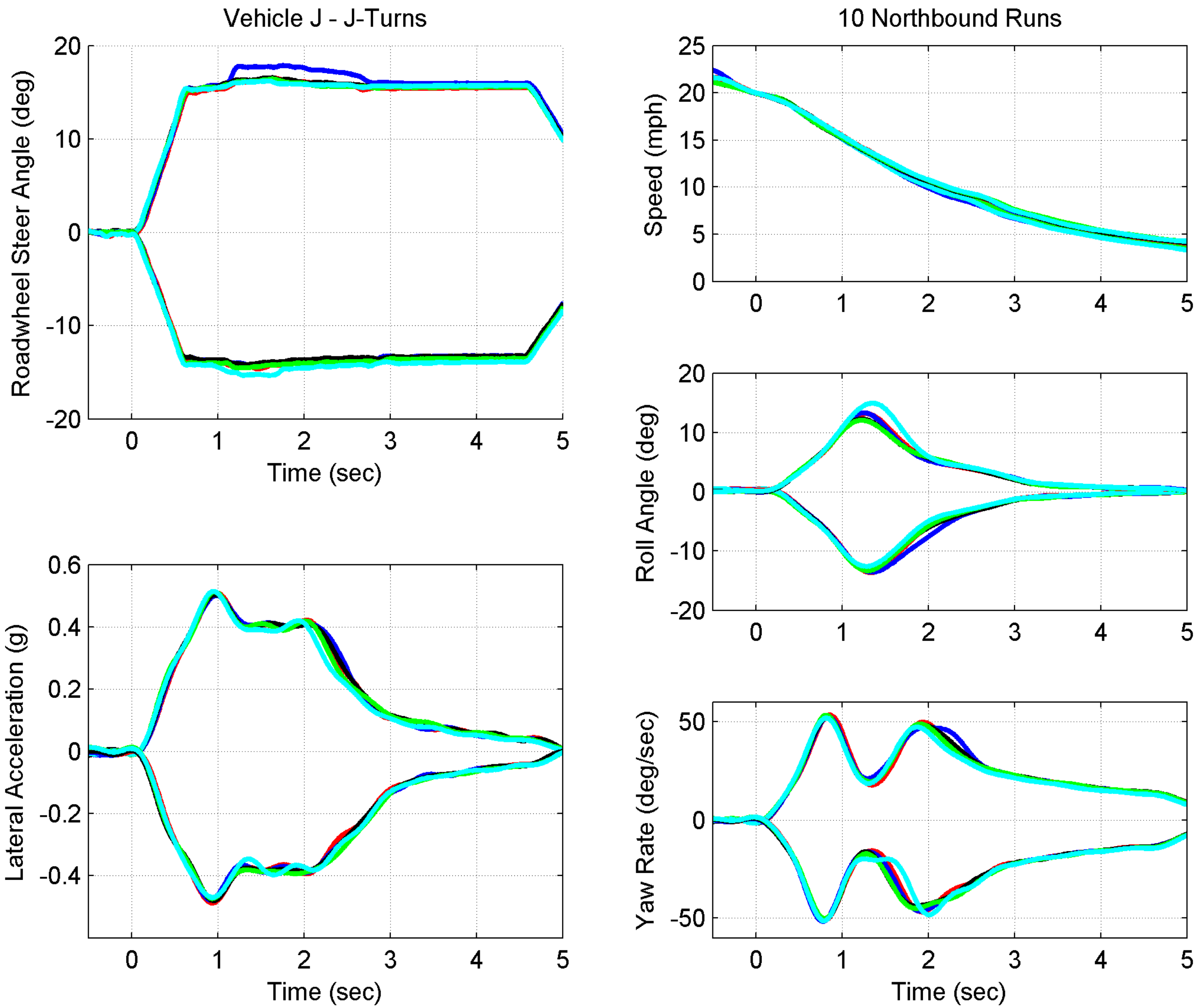
Vehicle J - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
50
100
150
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Time (sec)
Speed (mph)
25
20
CW
CCW
Roll Angle (deg)
Yaw Rate (deg/sec)
40
-20
-40


Vehicle J - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

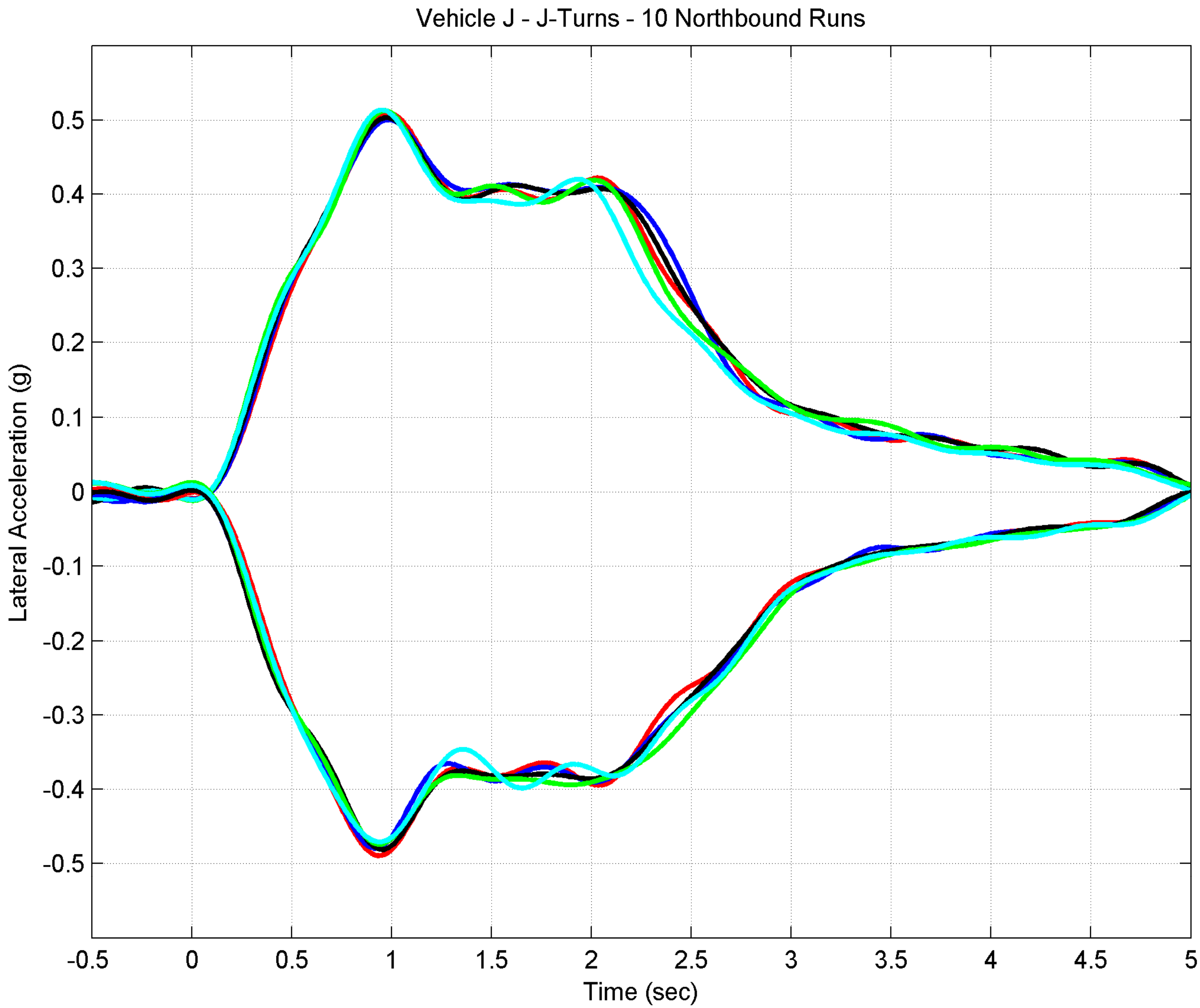


Vehicle J - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.159 g
CCW Transition to OS
At Ay = -0.147 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

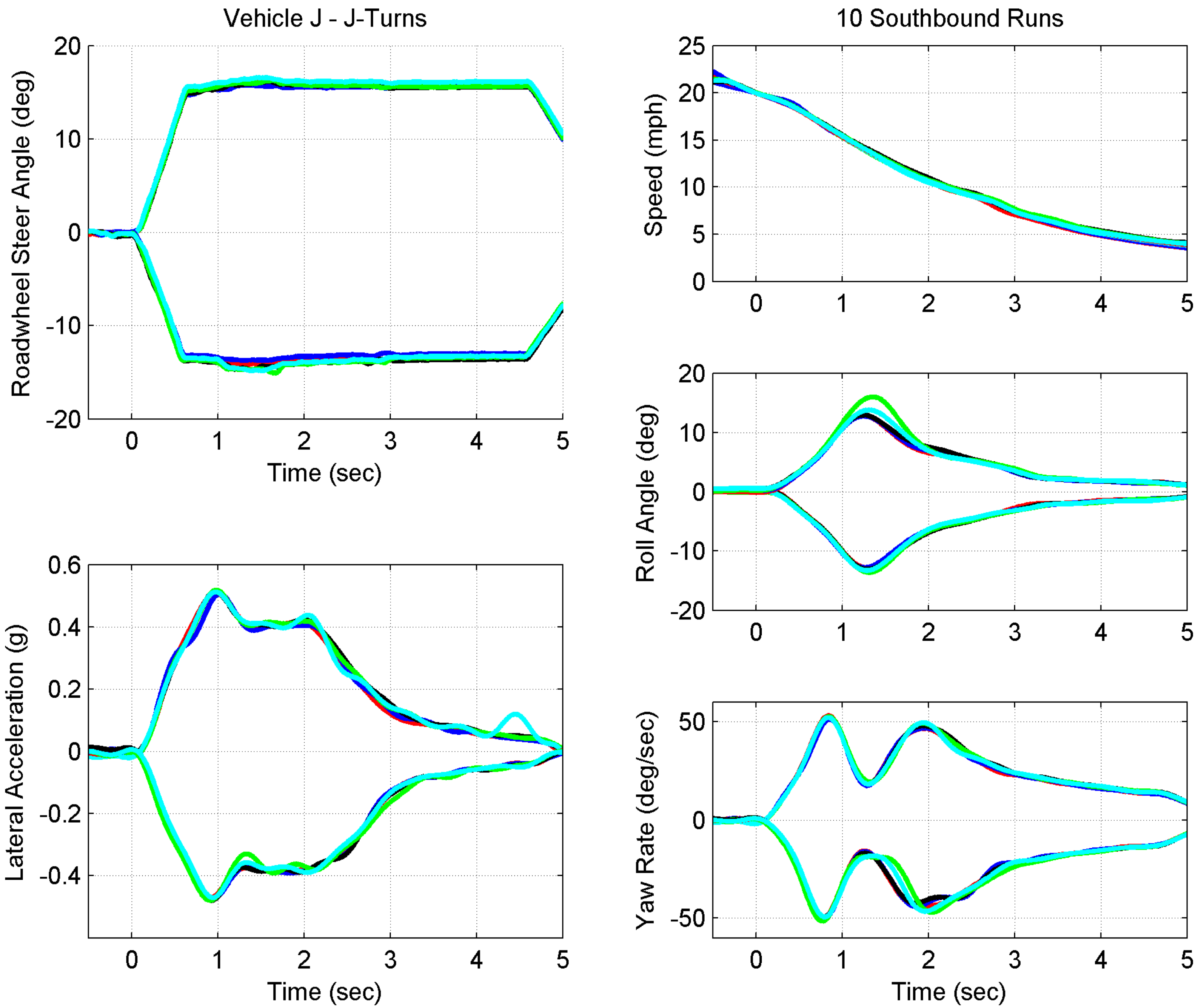

Vehicle J - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -13 deg/g
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5



Vehicle J - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

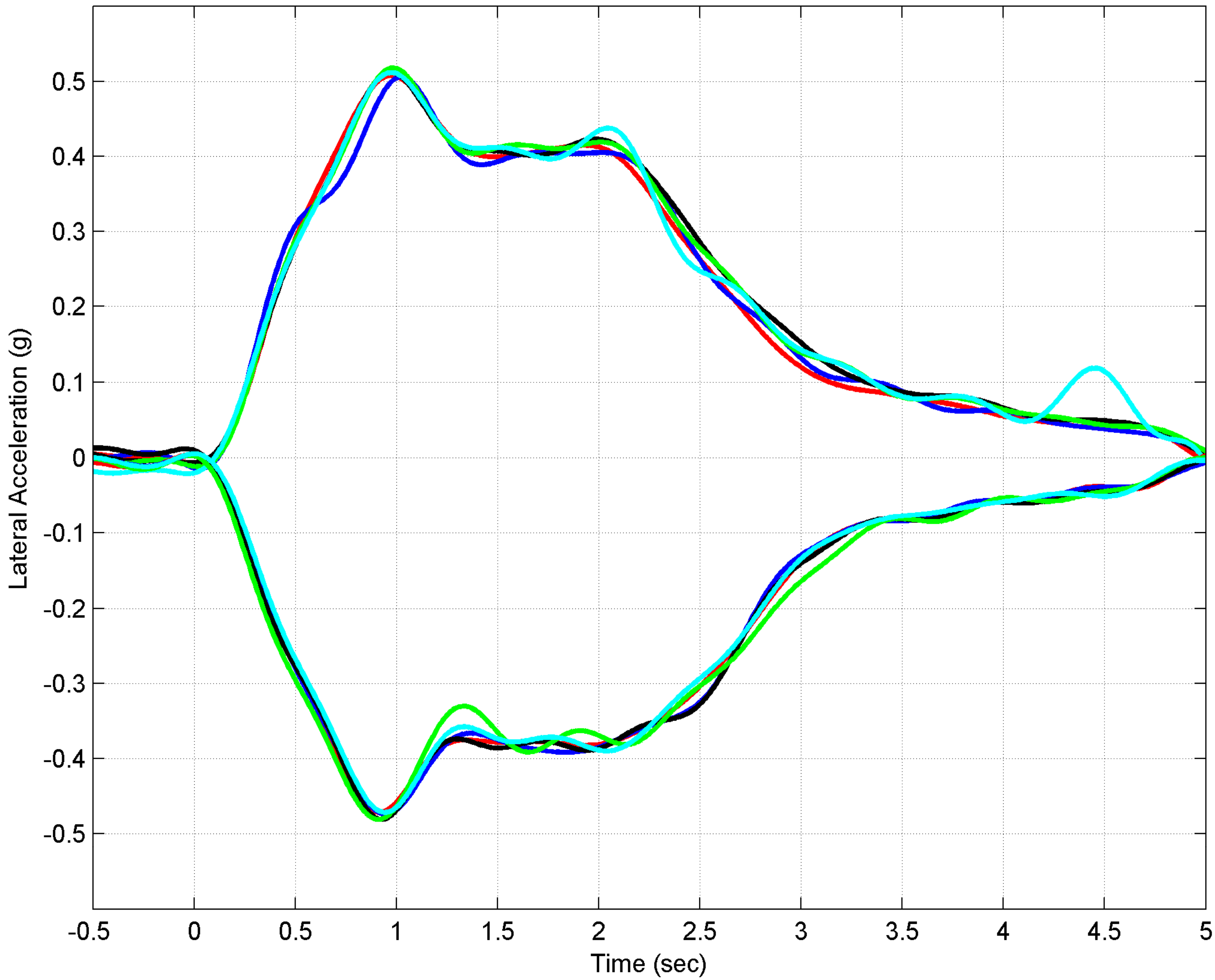


Vehicle J - J-Turns - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle J - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5
Time (sec)
Speed (mph)
25
20
15
10
5
0
Roll Angle (deg)
20
10
0
-10
-20
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Yaw Rate (deg/sec)
50
0
-50

Vehicle J - J-Turns - 10 Southbound Runs



Vehicle J

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

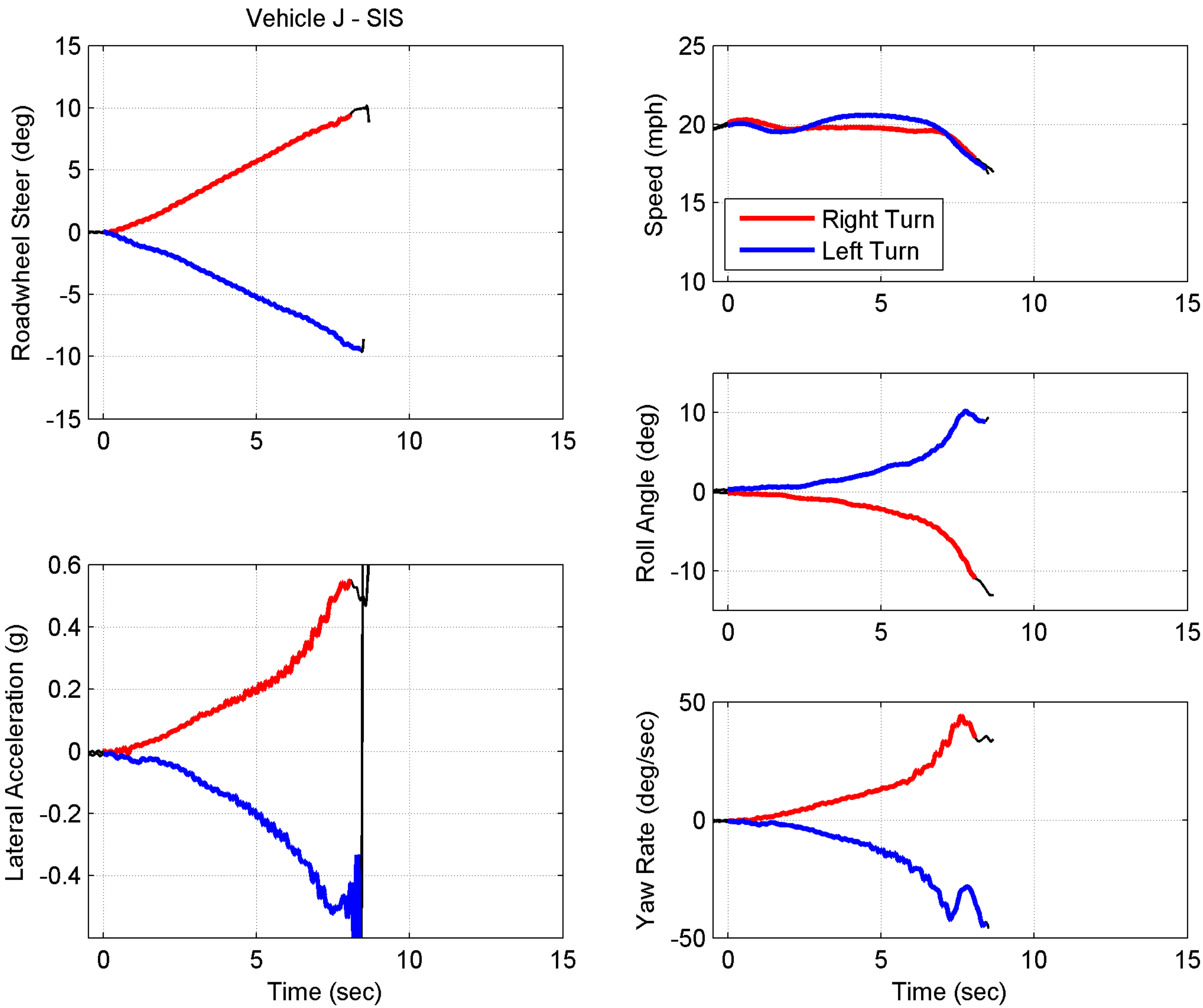
Run Number	Northbound Right Turns	Northbound Left Turns	
1	0.5086	-0.4894	
2	0.5003	-0.4796	
3	0.5032	-0.4813	
4	0.5125	-0.4744	
5	0.5135	-0.4711	**Average of 10 Northbound Runs**
Mean Value of 5 Runs	0.5076	-0.4791	**0.4934**
Standard Deviation of 5 Runs	0.006	0.007	

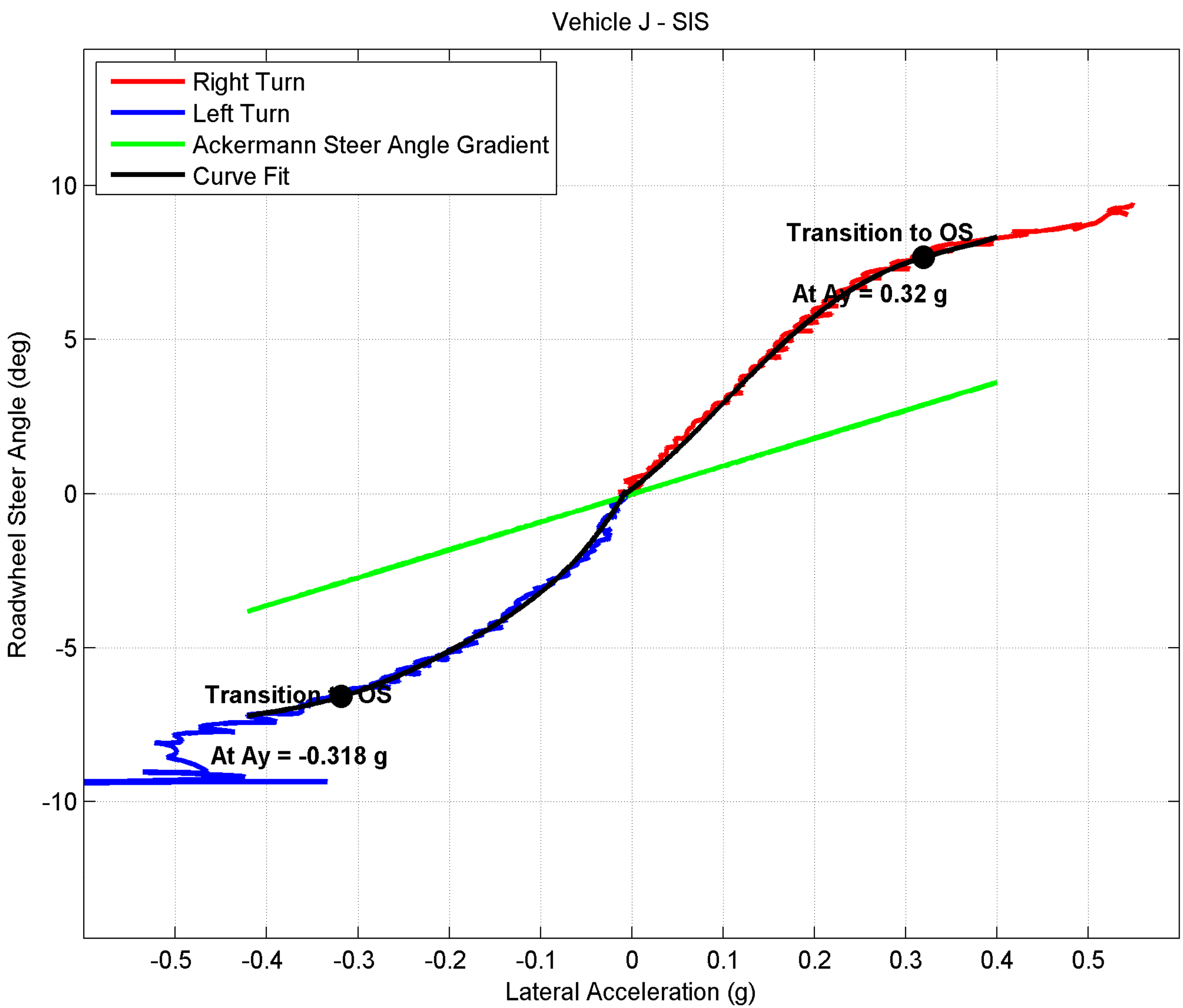
Average of All 20 Runs

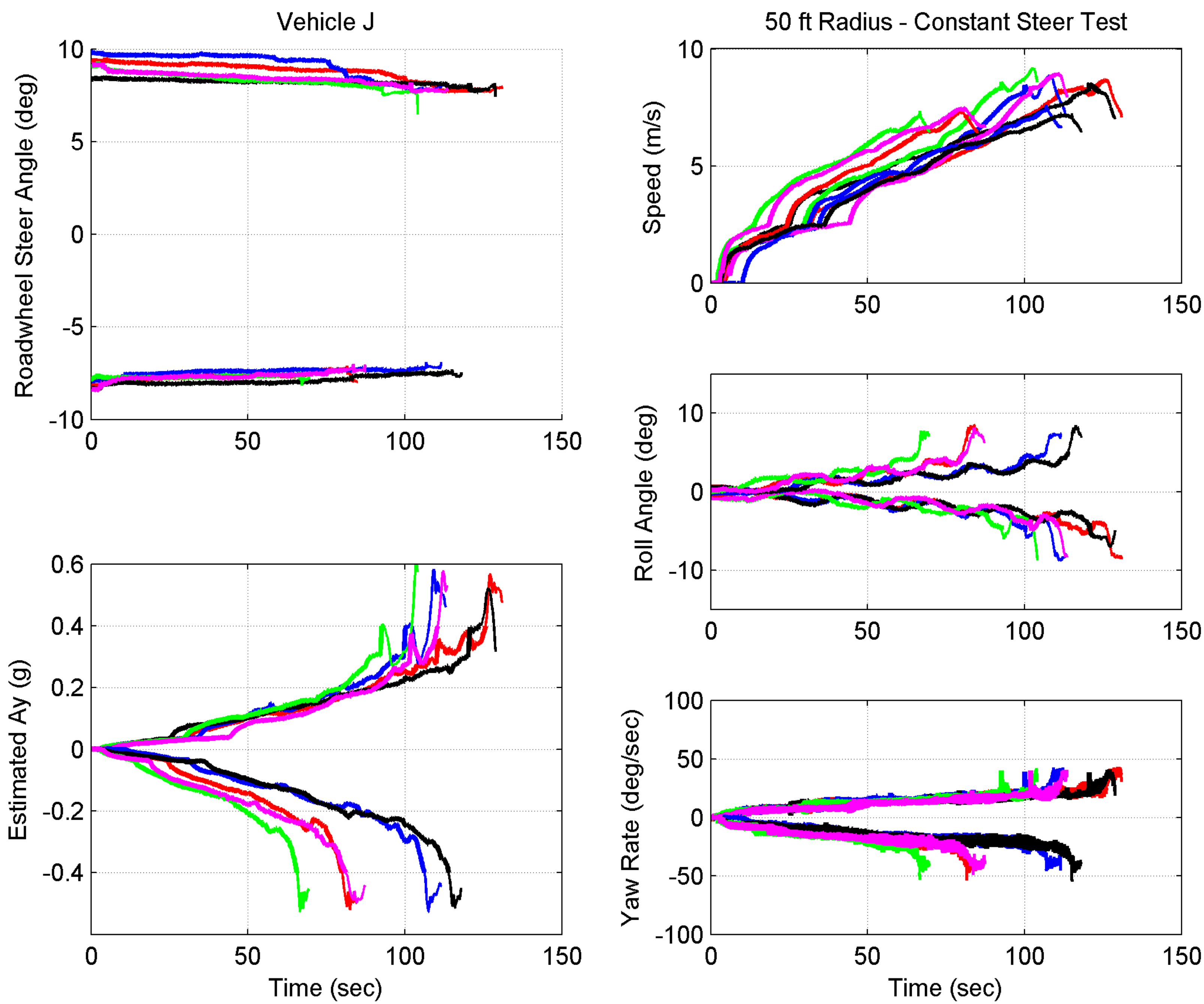
0.493

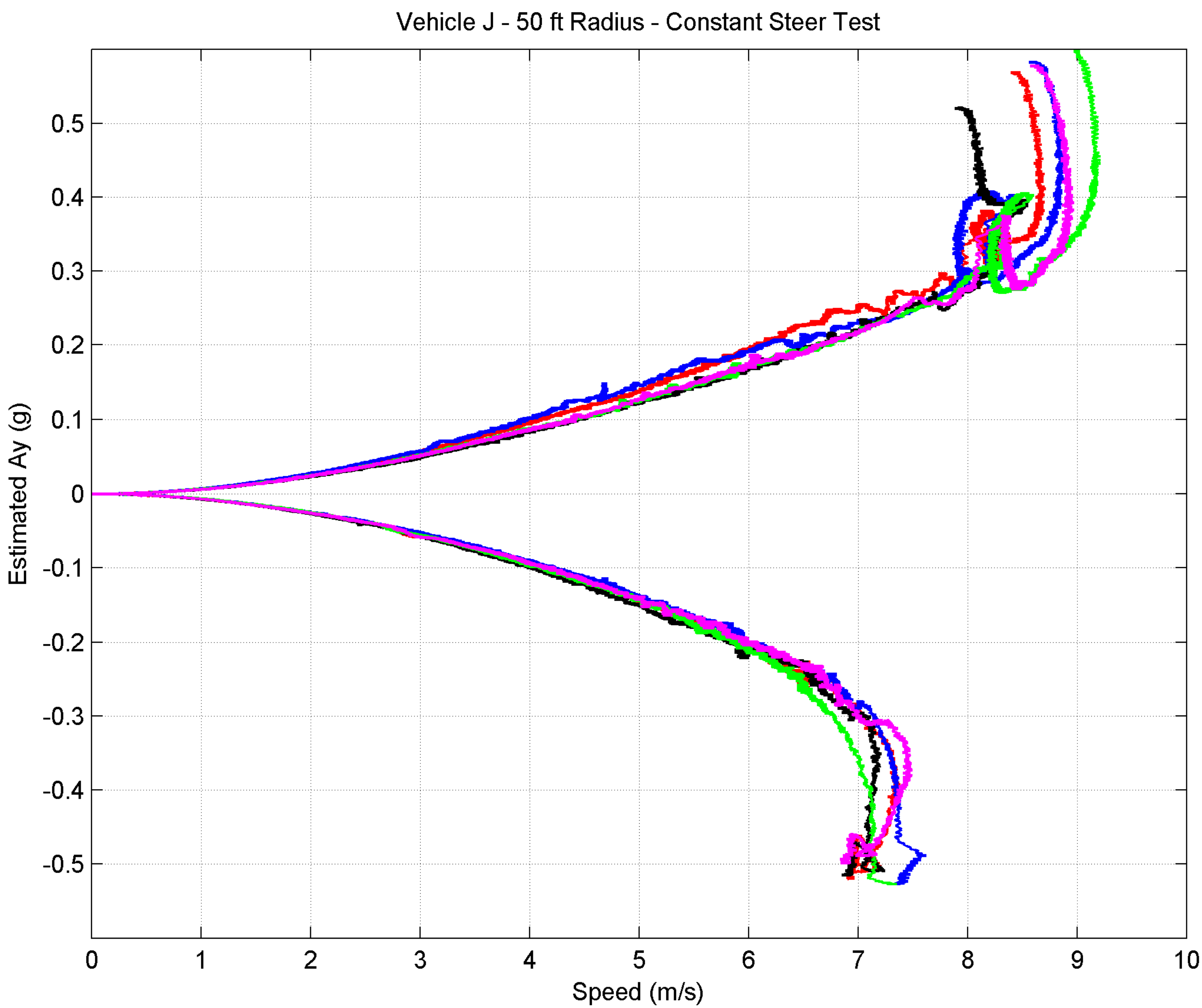
Threshold Ay

Run Number	Southbound Right Turns	Southbound Left Turns	
1	0.5078	-0.4717	
2	0.5060	-0.4739	
3	0.5120	-0.4809	
4	0.5179	-0.4809	
5	0.5116	-0.4716	**Average of 10 Southbound Runs**
Mean Value of 5 Runs	0.5111	-0.4758	**0.4934**
Standard Deviation of 5 Runs	0.005	0.005	

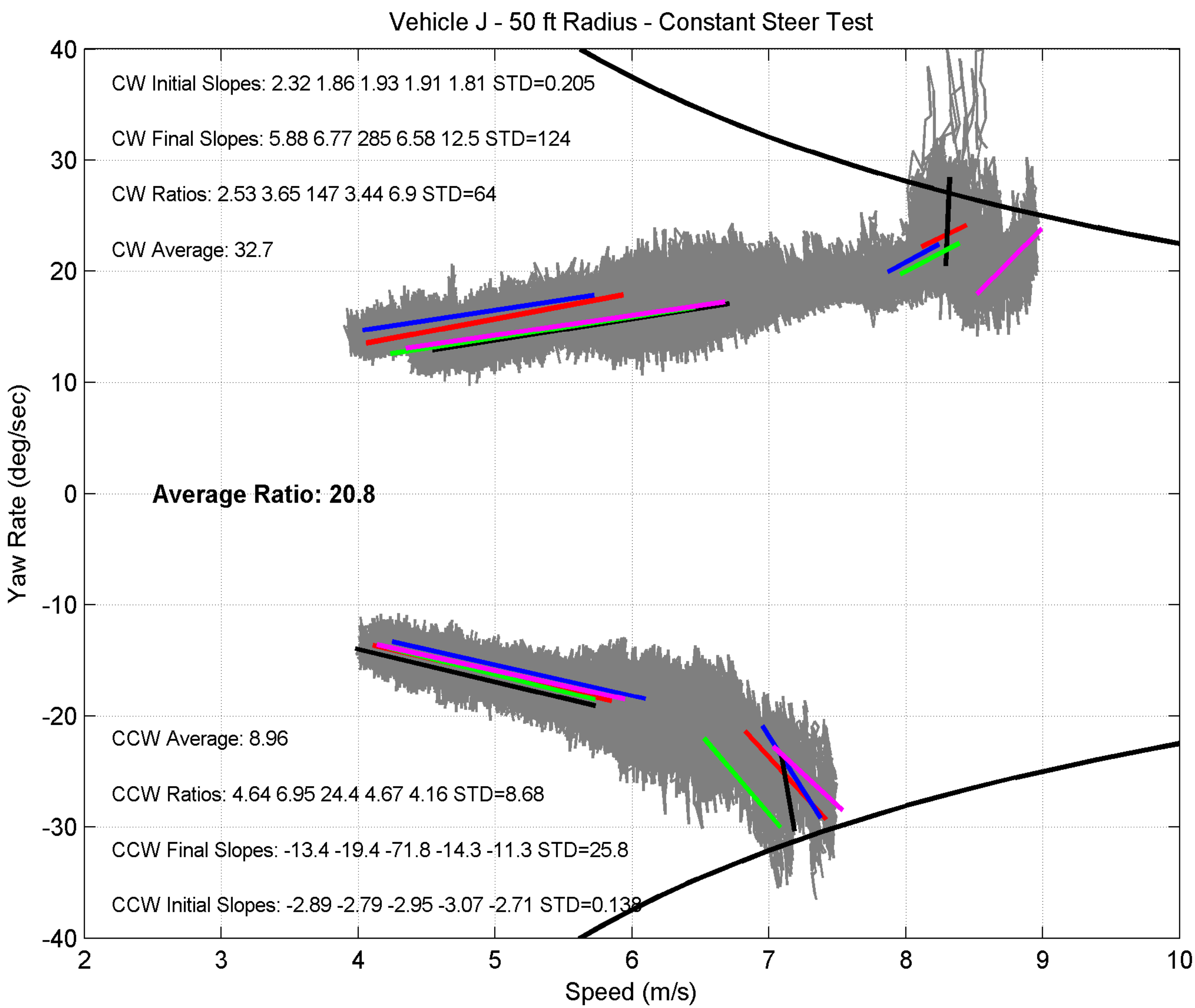

Vehicle J - SIS
Roadwheel Steer (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

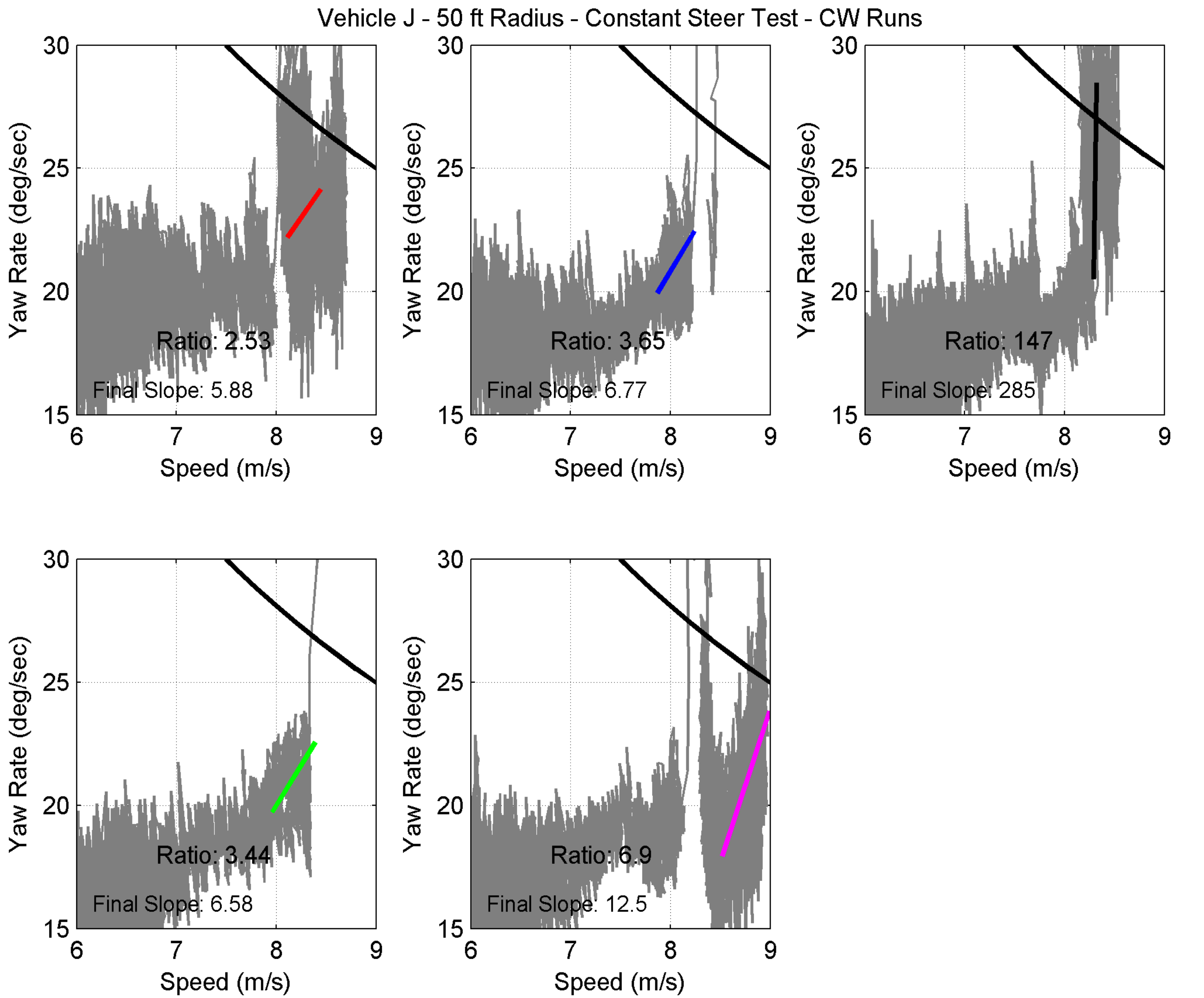

Vehicle J - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to OS
At Ay = 0.32 g
Transition to OS
At Ay = -0.318 g
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
10
5
0
-5
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5


Vehicle J
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

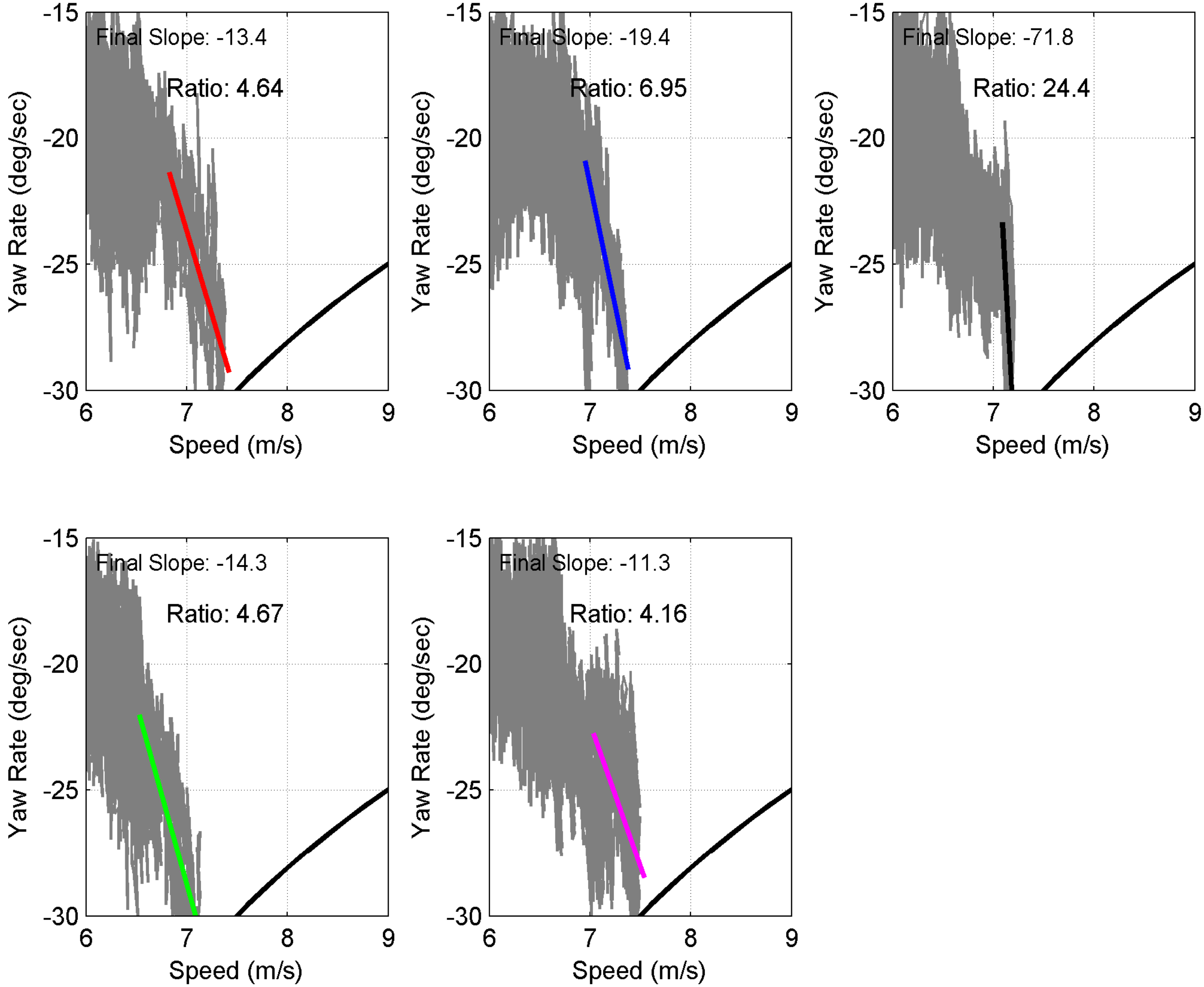


Vehicle J - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10

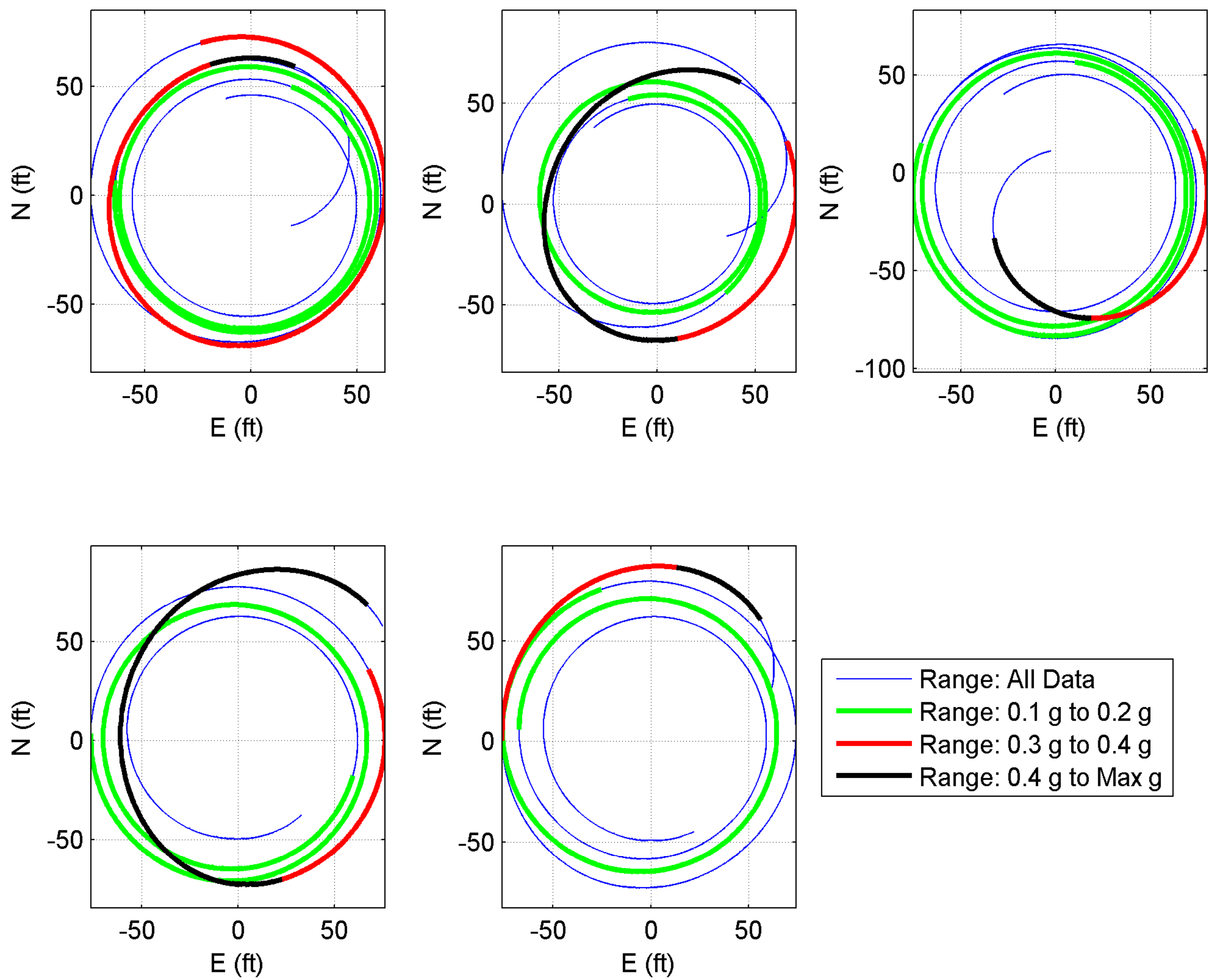

Vehicle J - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 2.32 1.86 1.93 1.91 1.81 STD=0.205
CW Final Slopes: 5.88 6.77 285 6.58 12.5 STD=124
CW Ratios: 2.53 3.65 147 3.44 6.9 STD=64
CW Average: 32.7
Average Ratio: 20.8
CCW Average: 8.96
CCW Ratios: 4.64 6.95 24.4 4.67 4.16 STD=8.68
CCW Final Slopes: -13.4 -19.4 -71.8 -14.3 -11.3 STD=25.8
CCW Initial Slopes: -2.89 -2.79 -2.95 -3.07 -2.71 STD=0.138
Yaw Rate (deg/sec)
Speed (m/s)
40
30
20
10
0
-10
-20
-30
-40
2
3
4
5
6
7
8
9
10


Vehicle J - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 2.53
Final Slope: 5.88
Ratio: 3.65
Final Slope: 6.77
Ratio: 147
Final Slope: 285
Ratio: 3.44
Final Slope: 6.58
Ratio: 6.9
Final Slope: 12.5

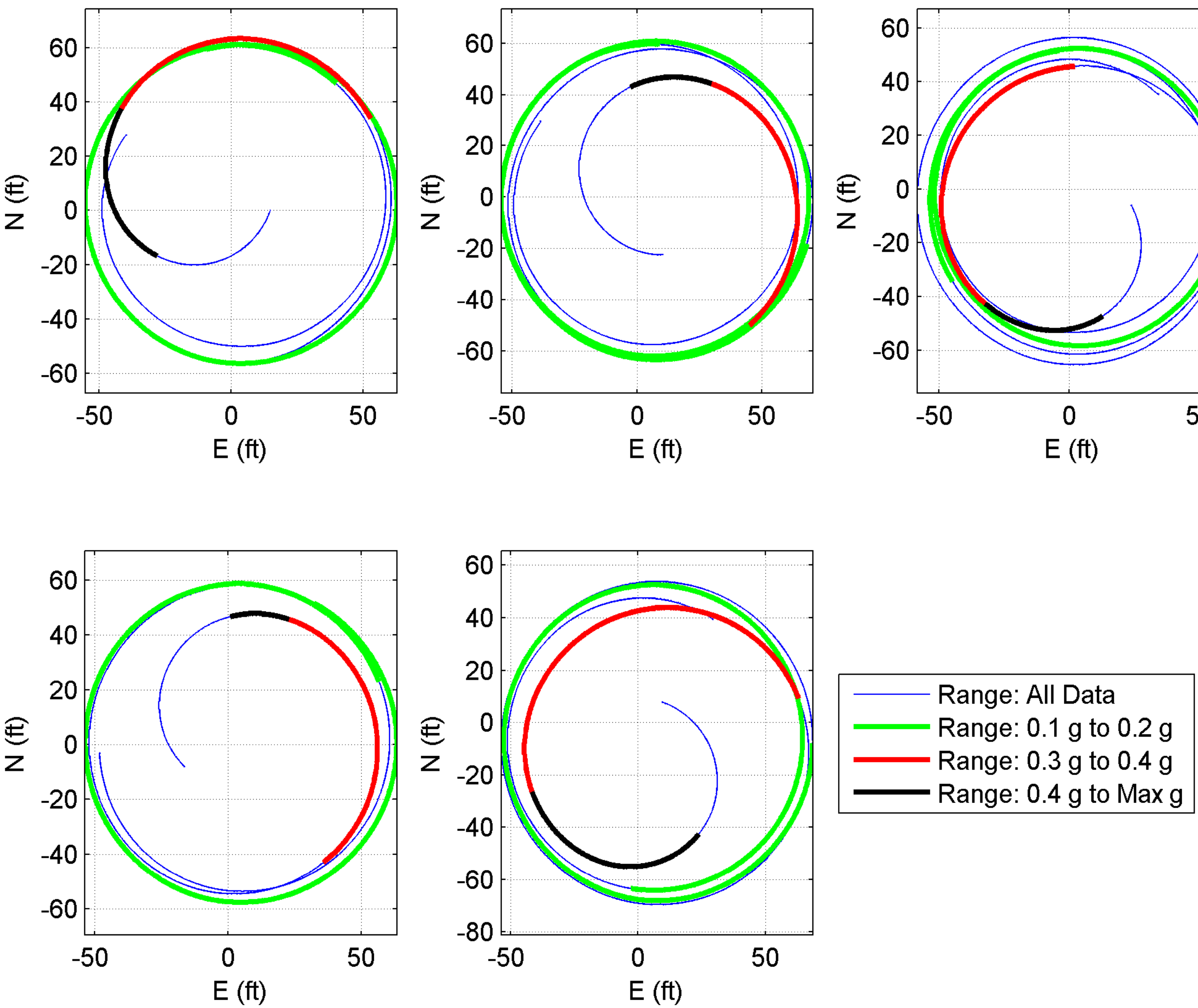
Vehicle J - 50 ft Radius - Constant Steer Test - CCW Runs

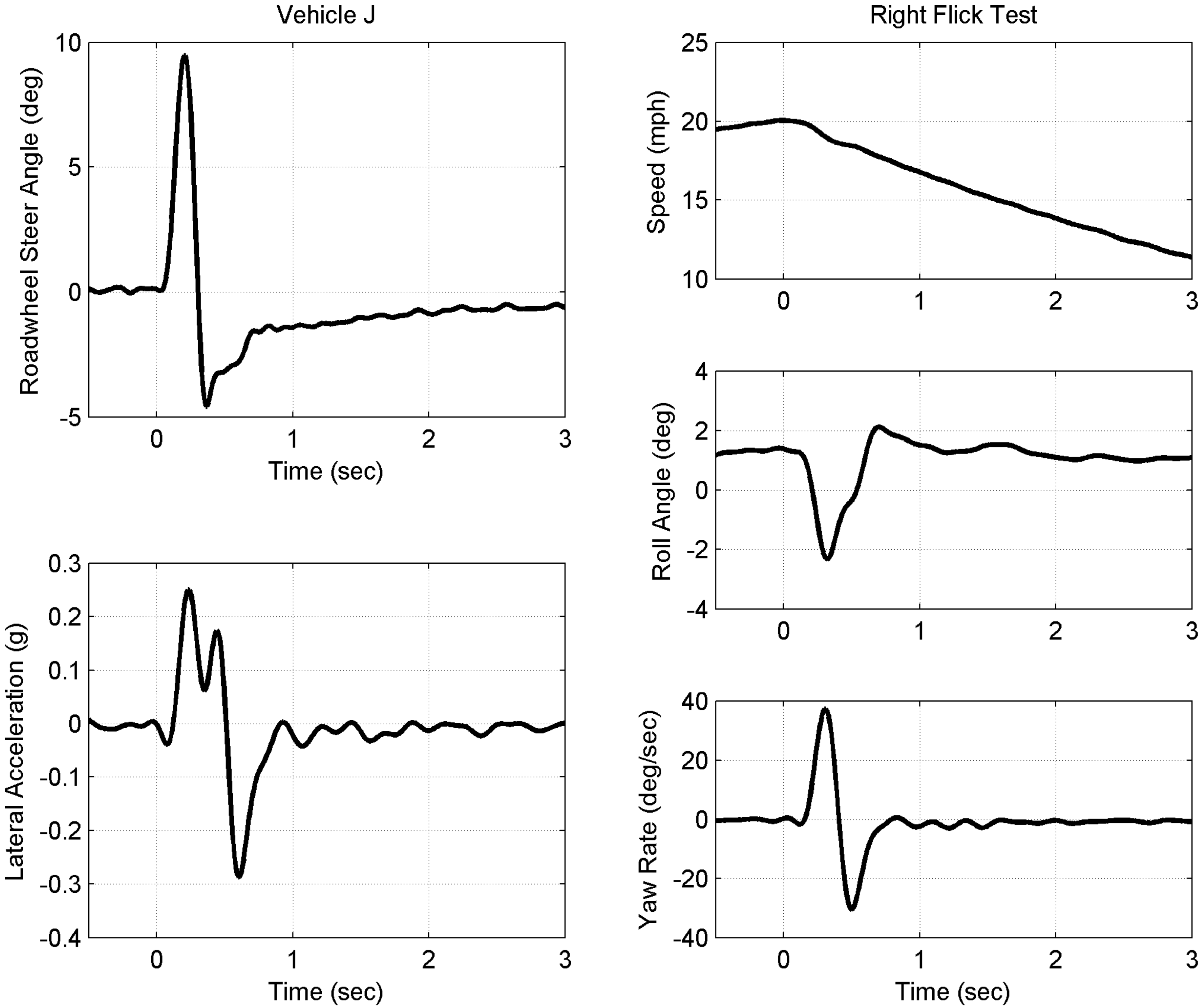


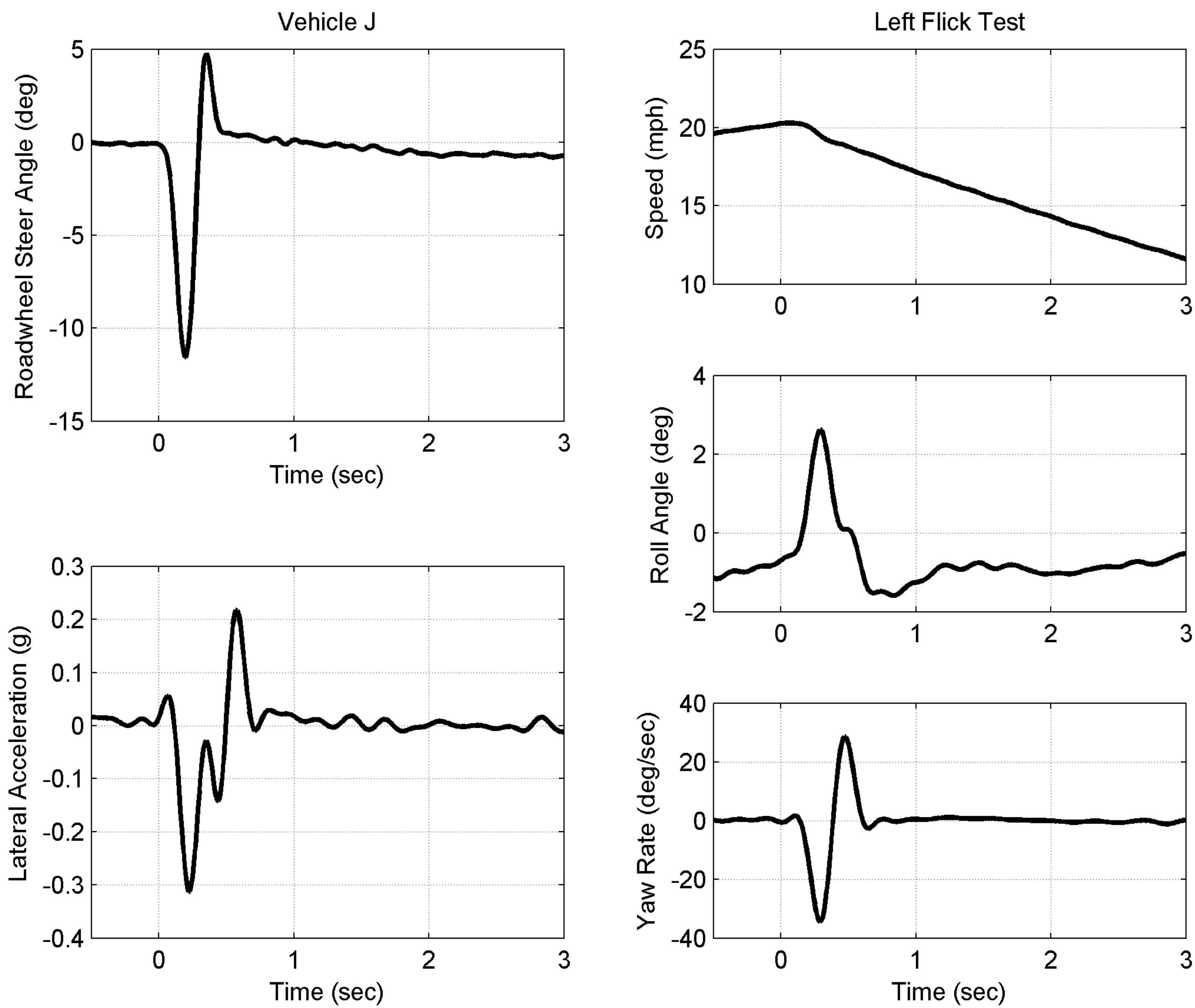
Vehicle J - 50 ft Radius - Constant Steer Test - CW Runs

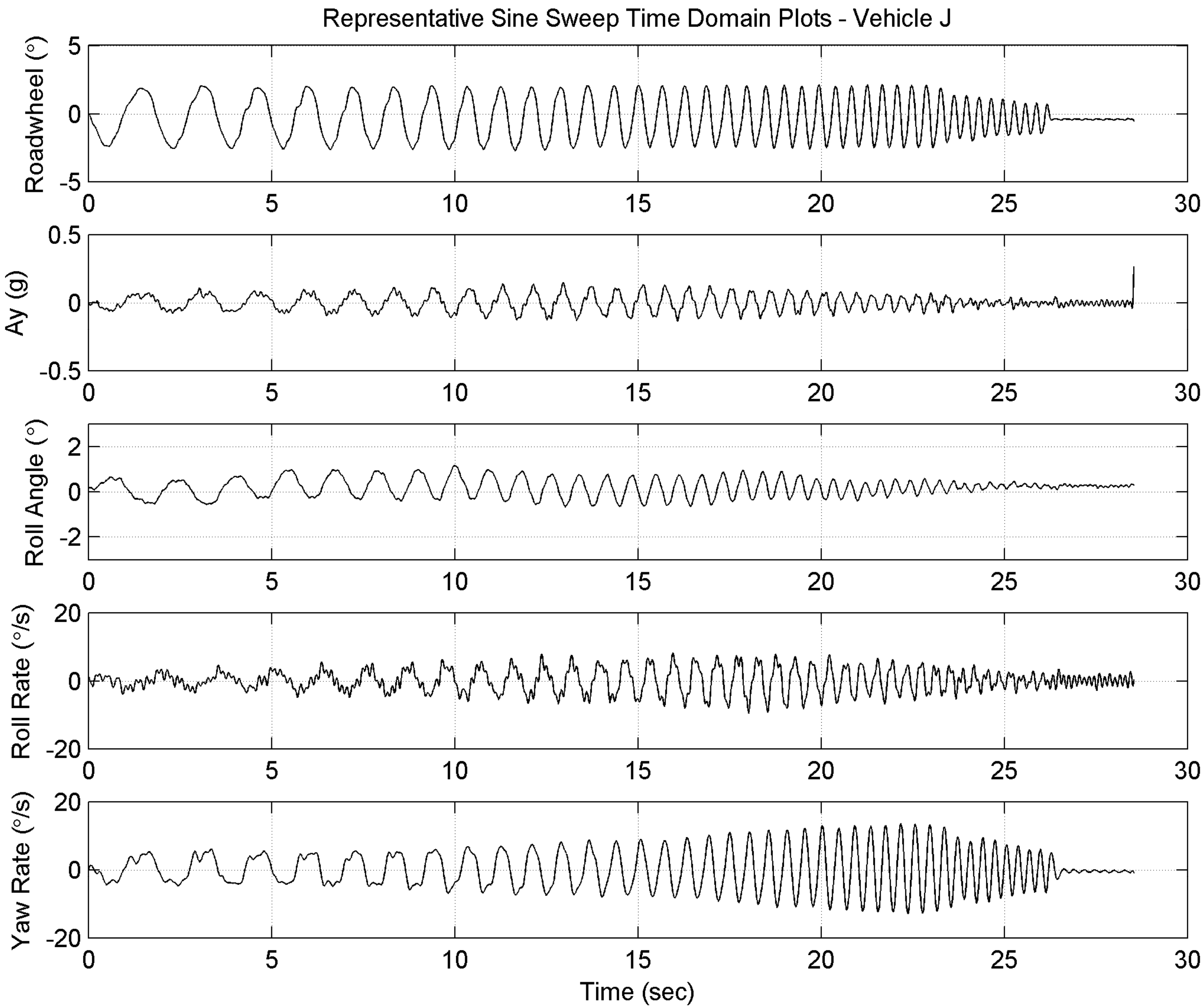


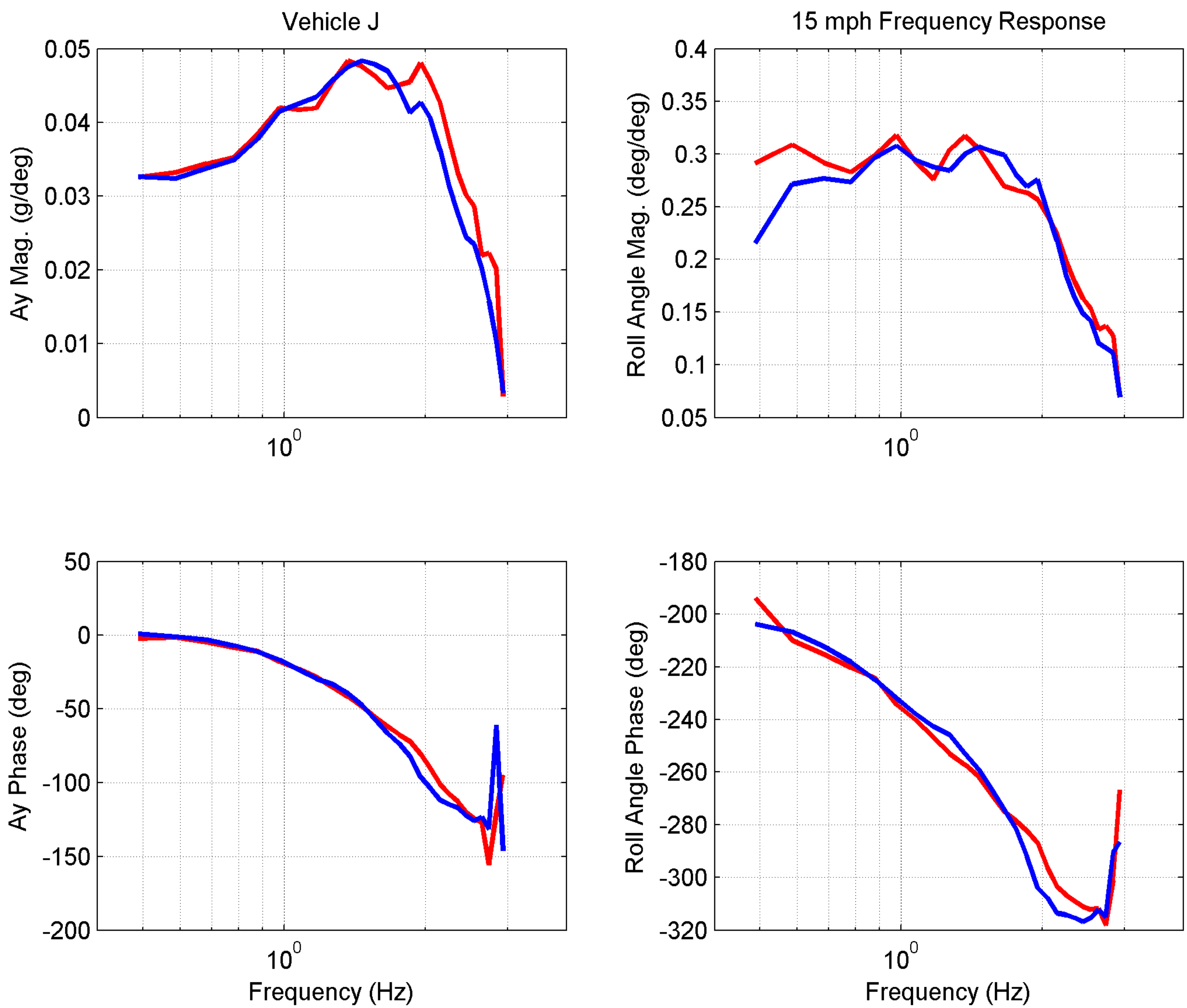
Vehicle J - 50 ft Radius - Constant Steer Test - CCW Runs



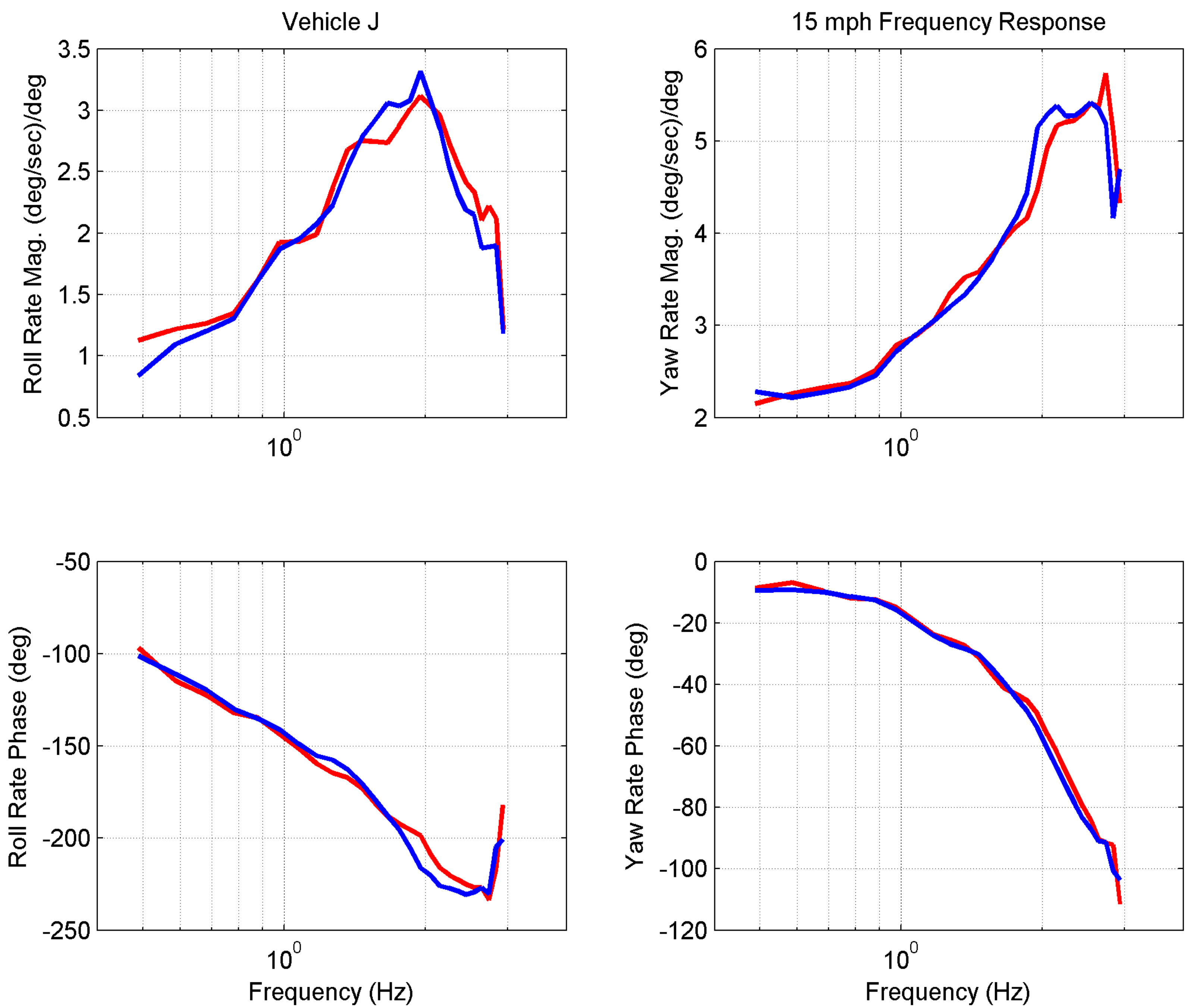

Vehicle J
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

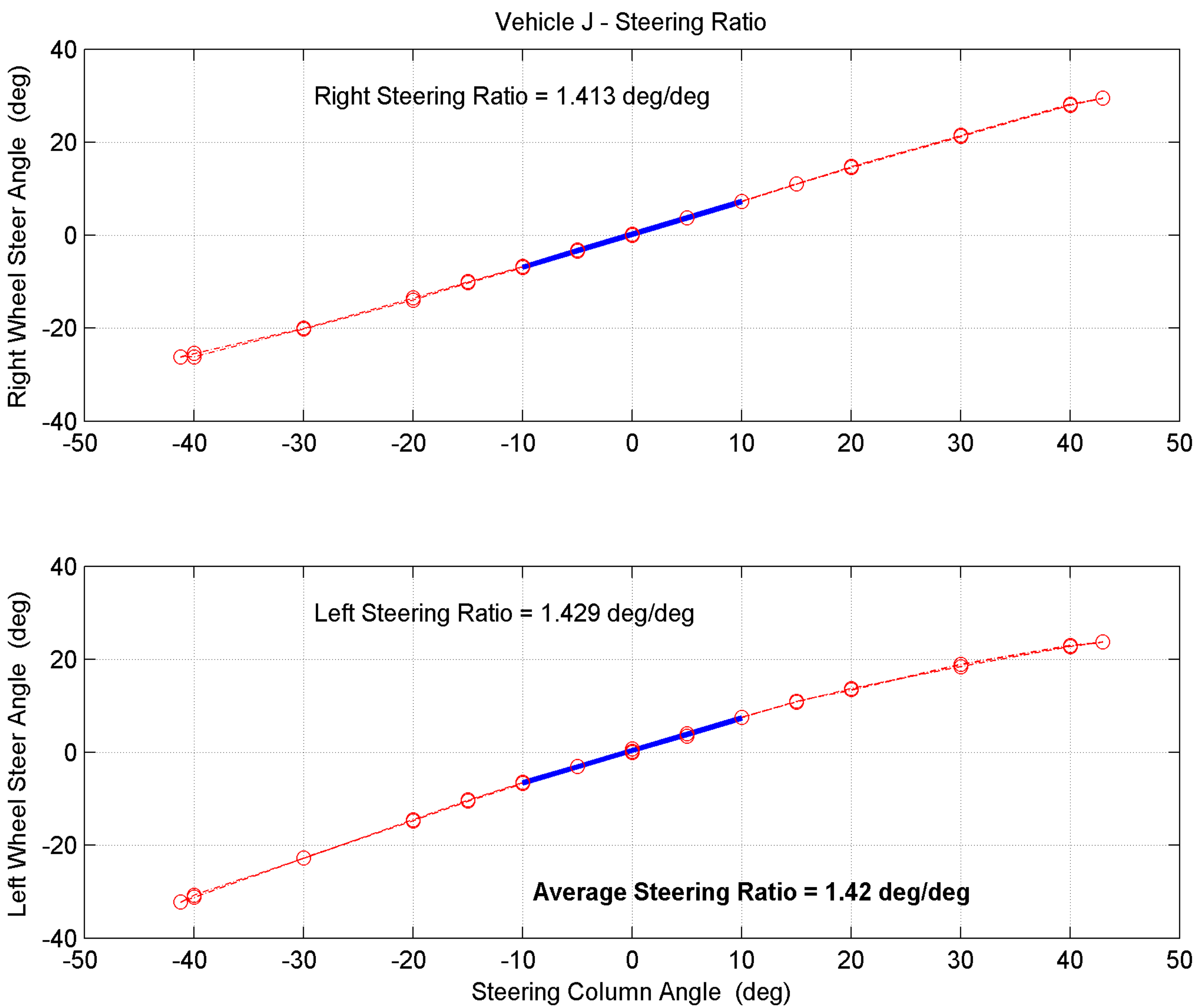

Vehicle J
Left Flick Test
Roadwheel Steer Angle (deg)
5
0
-5
-10
-15
0
1
2
3
Time (sec)
Speed (mph)
25
20
15
10
Roll Angle (deg)
4
2
0
-2
Lateral Acceleration (g)
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)

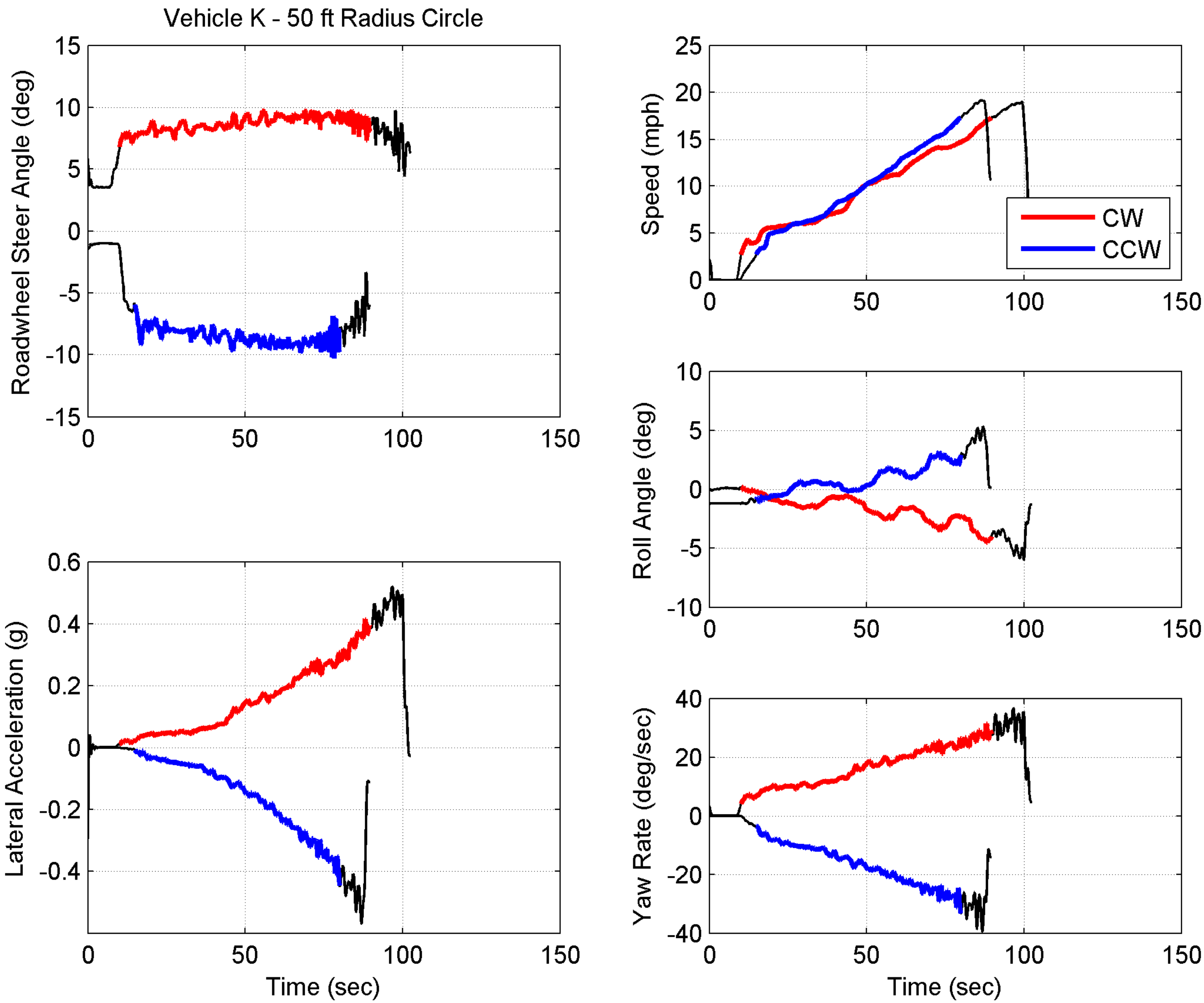

Representative Sine Sweep Time Domain Plots - Vehicle J
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)



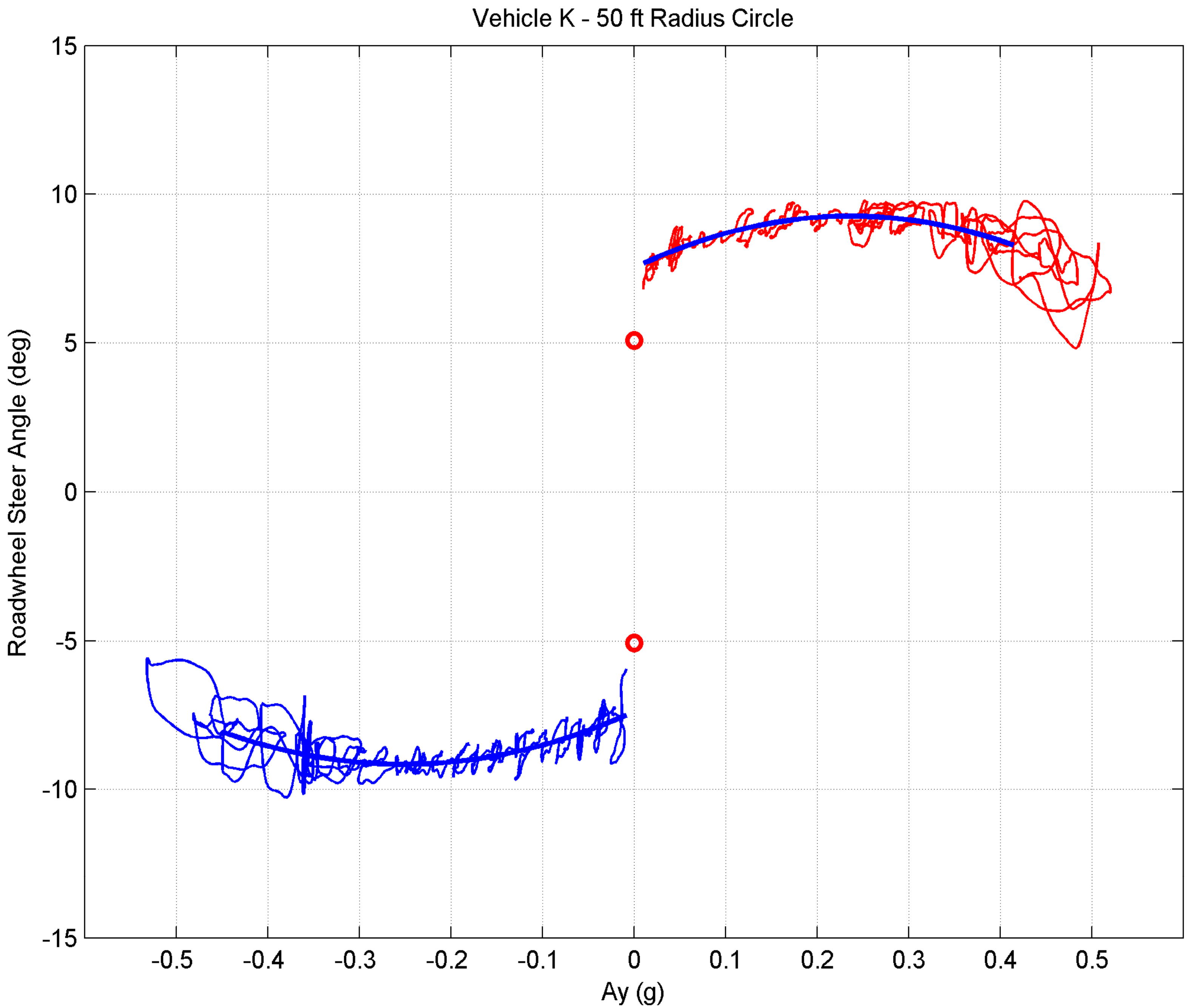
Vehicle J
15 mph Frequency Response
Ay Mag. (g/deg)
0.05
0.04
0.03
0.02
0.01
0
Roll Angle Mag. (deg/deg)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Ay Phase (deg)
50
0
-50
-100
-150
-200
Roll Angle Phase (deg)
-180
-200
-220
-240
-260
-280
-300
-320
10^0
Frequency (Hz)


Vehicle J
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
3.5
3
2.5
2
1.5
1
0.5
6
5
4
3
2
-50
-100
-150
-200
-250
0
-20
-40
-60
-80
-100
-120
10^0

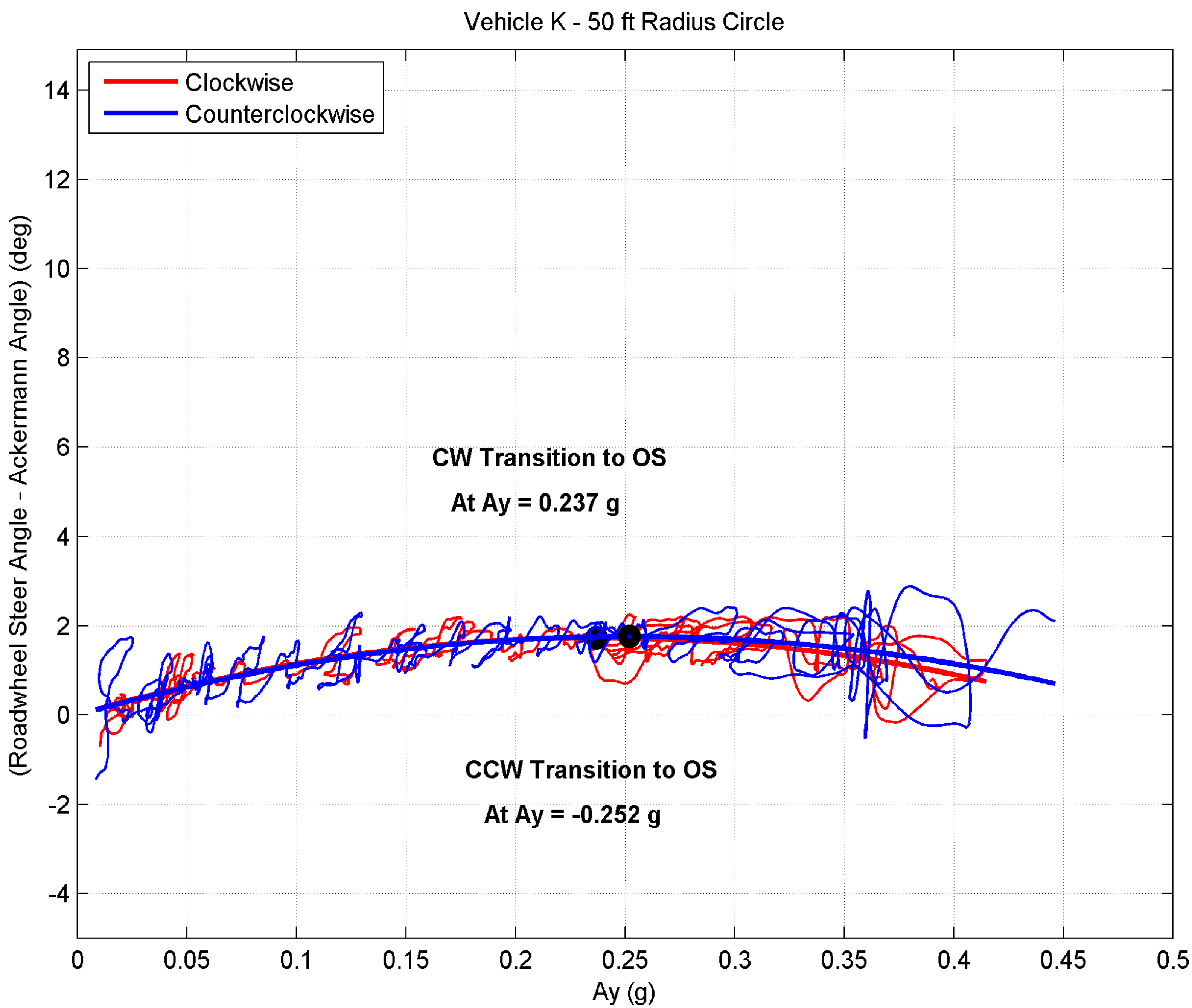

Vehicle J - Steering Ratio
Right Steering Ratio = 1.413 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-50
-40
-30
-20
-10
0
10
20
30
40
50
Left Steering Ratio = 1.429 deg/deg
Average Steering Ratio = 1.42 deg/deg
Left Wheel Steer Angle (deg)
Steering Column Angle (deg)



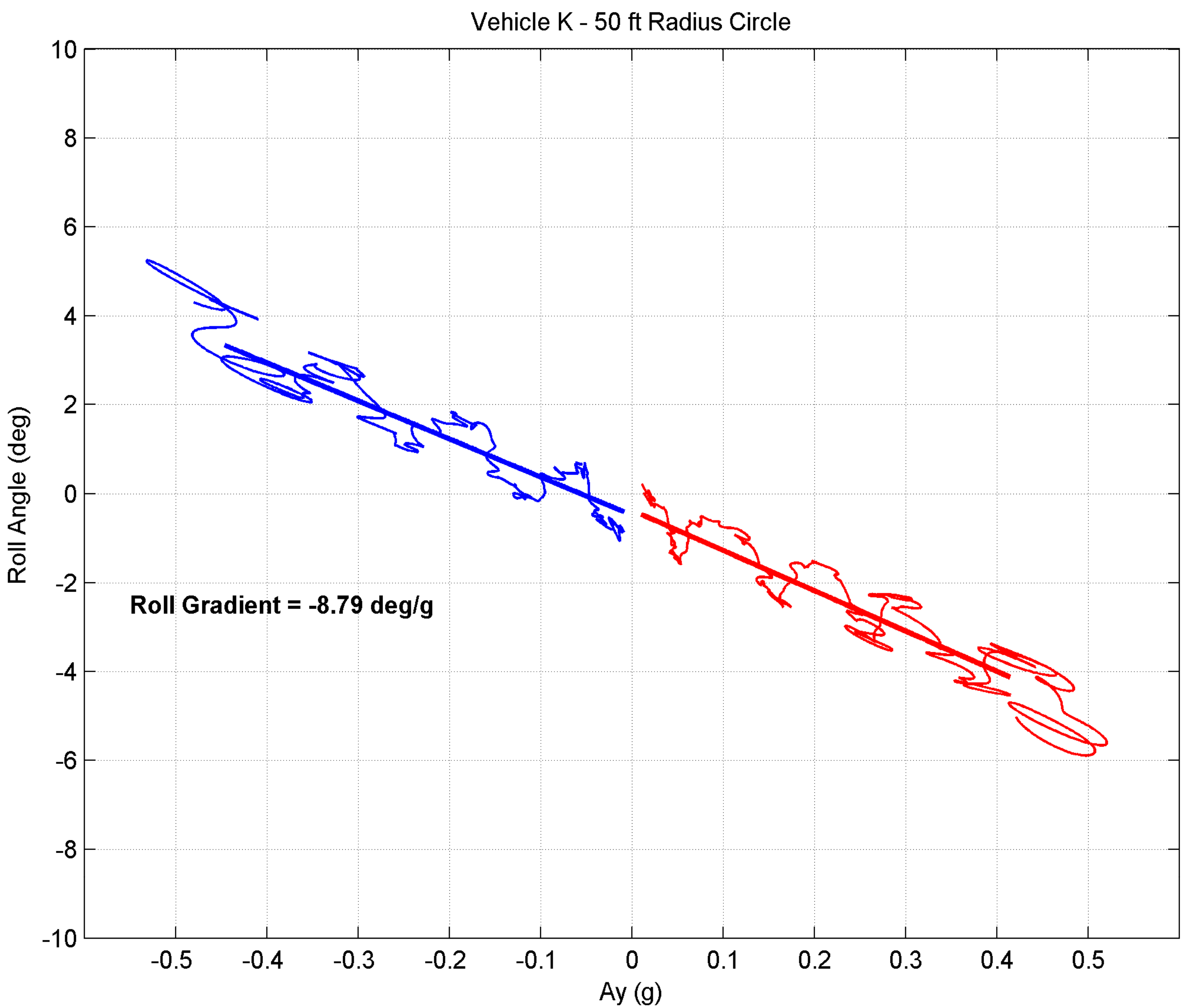
Vehicle K - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



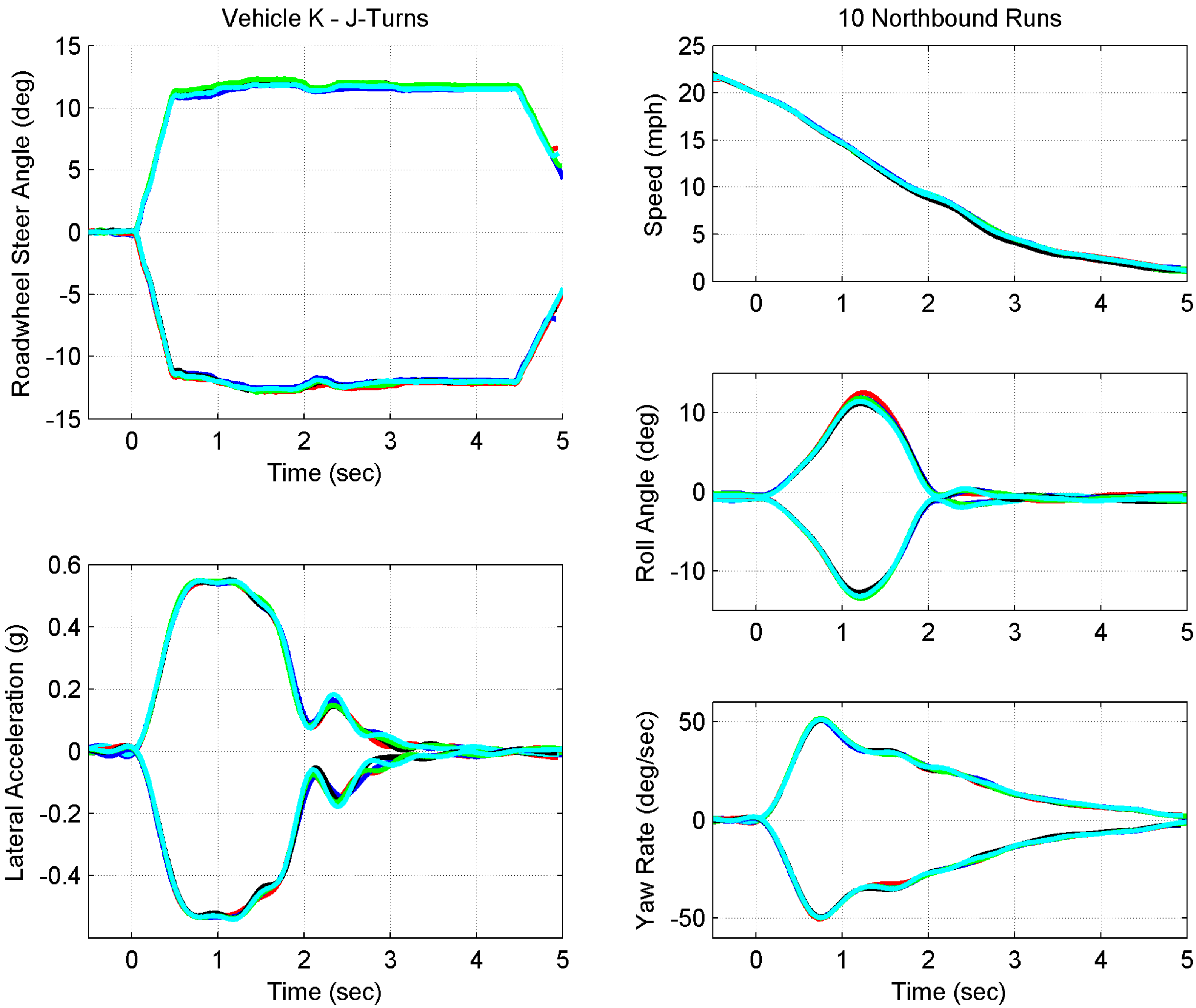
Vehicle K - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5



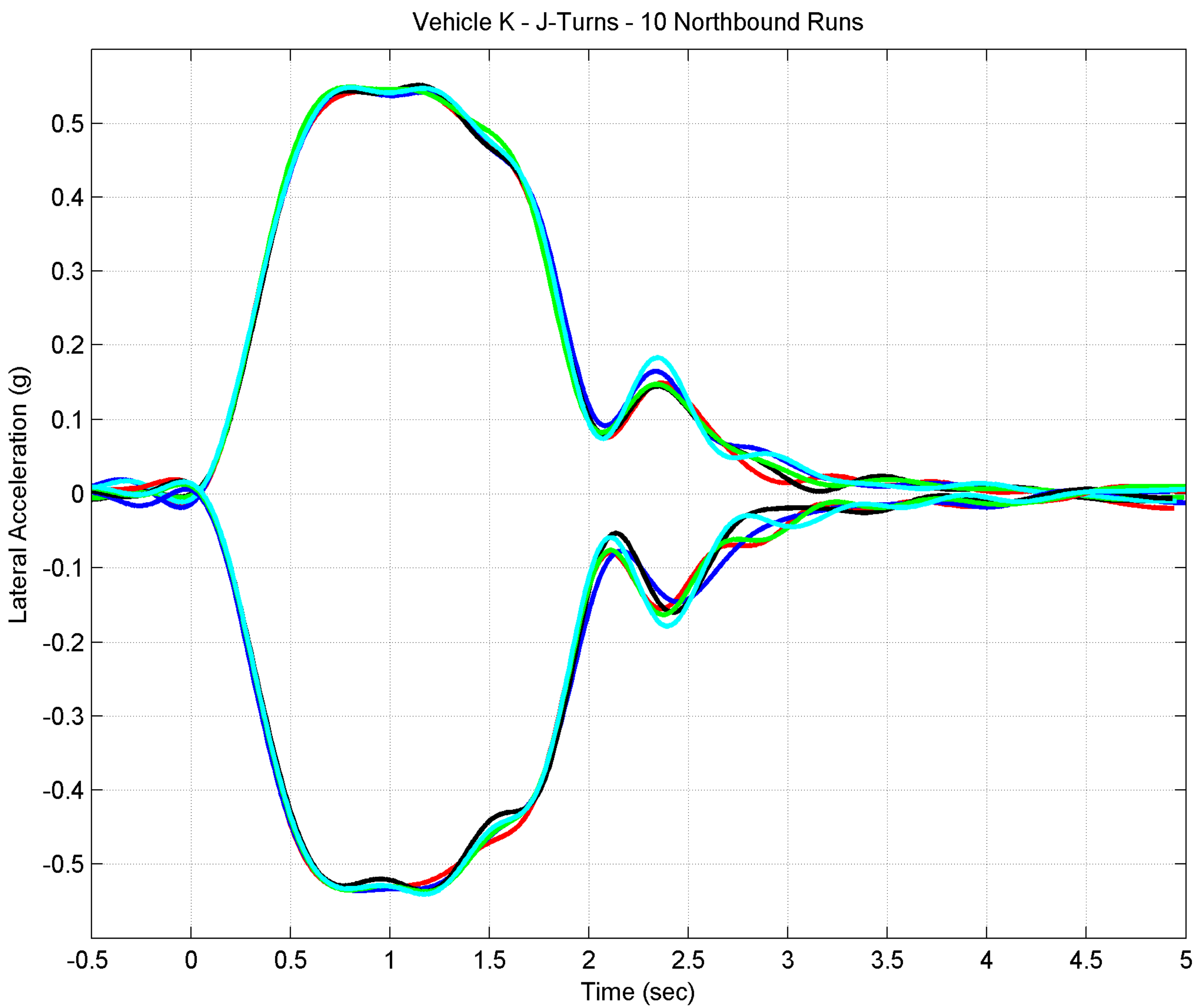
Vehicle K - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.237 g
CCW Transition to OS
At Ay = -0.252 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
14
12
10
8
6
4
2
0
-2
-4
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5



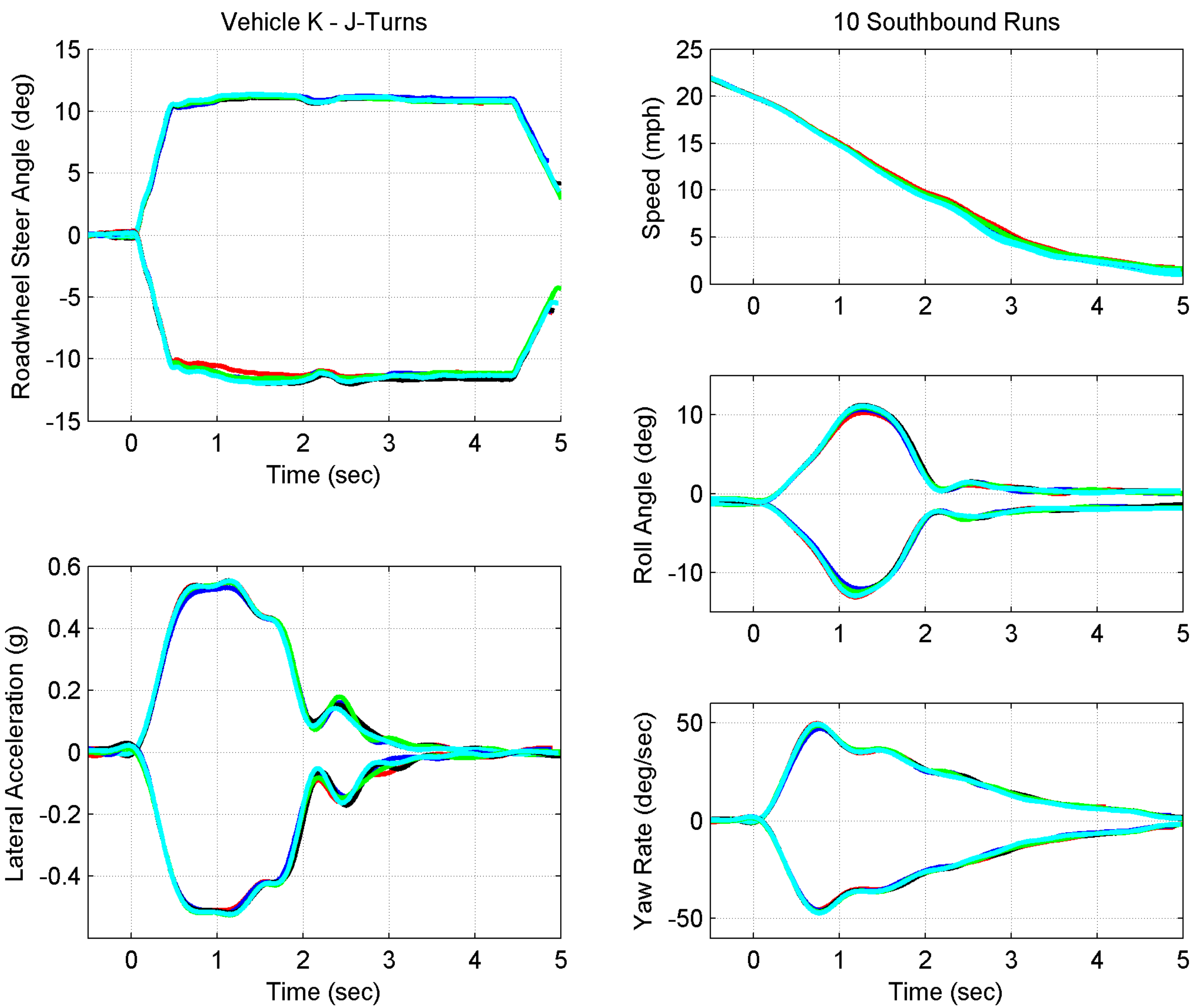
Vehicle K - 50 ft Radius Circle
Roll Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)
Roll Gradient = -8.79 deg/g



Vehicle K - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)
Speed (mph)
25
20
15
10
5
0
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Yaw Rate (deg/sec)
50
0
-50

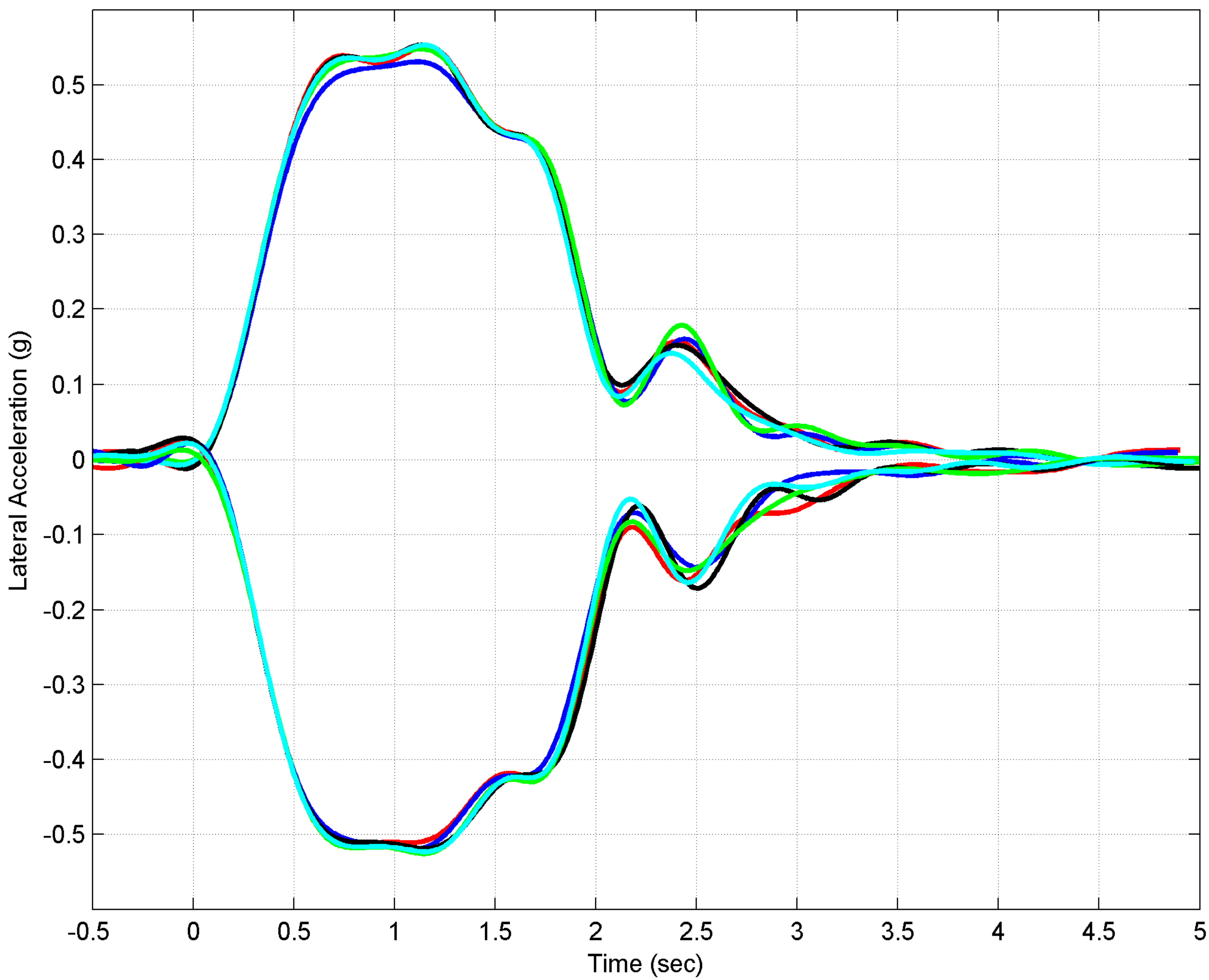


Vehicle K - J-Turns - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle K - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

Vehicle K - J-Turns - 10 Southbound Runs



Vehicle K

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.5449	-0.5356
2	0.5461	-0.5362
3	0.5513	-0.5375
4	0.5489	-0.5377
5	0.5482	-0.5411
Mean Value of 5 Runs	0.5479	-0.5376
Standard Deviation of 5 Runs	0.003	0.002

Average of 10 Northbound Runs

0.5427

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.5514	-0.5137
2	0.5307	-0.5202
3	0.5532	-0.5189
4	0.5478	-0.5261
5	0.5530	-0.5236
Mean Value of 5 Runs	0.5472	-0.5205
Standard Deviation of 5 Runs	0.009	0.005

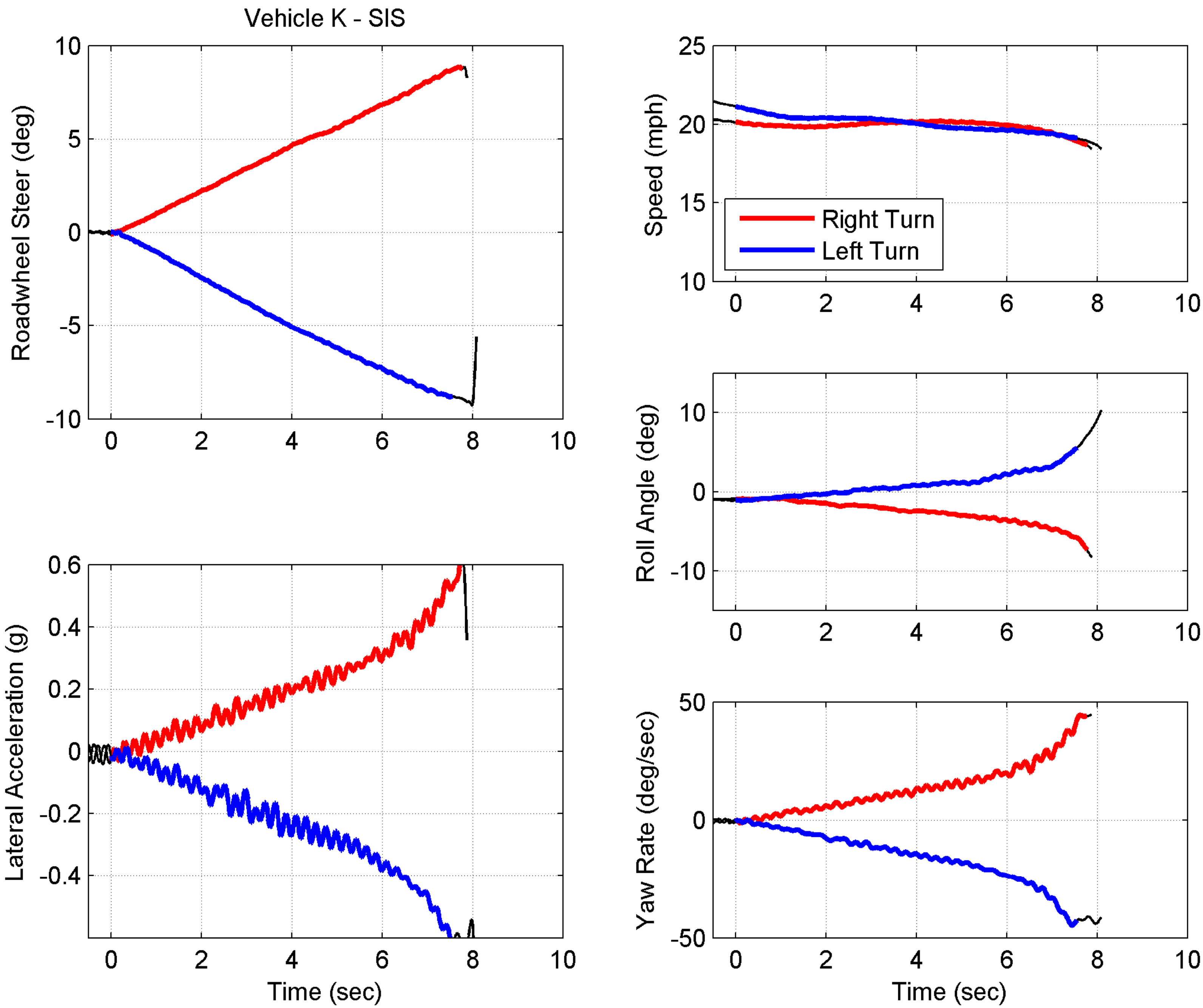
Average of 10 Southbound Runs

0.5339

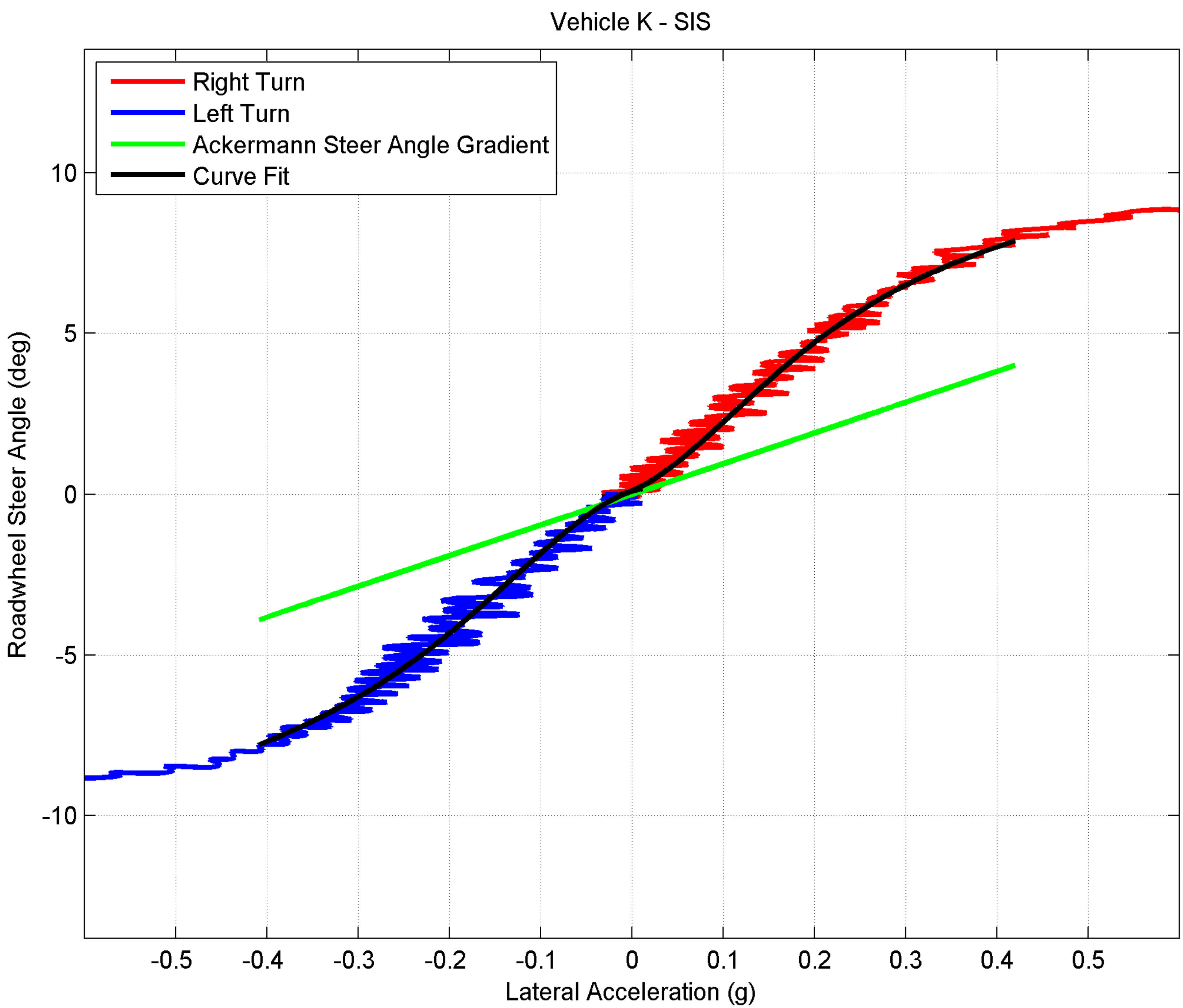
Average of All 20 Runs

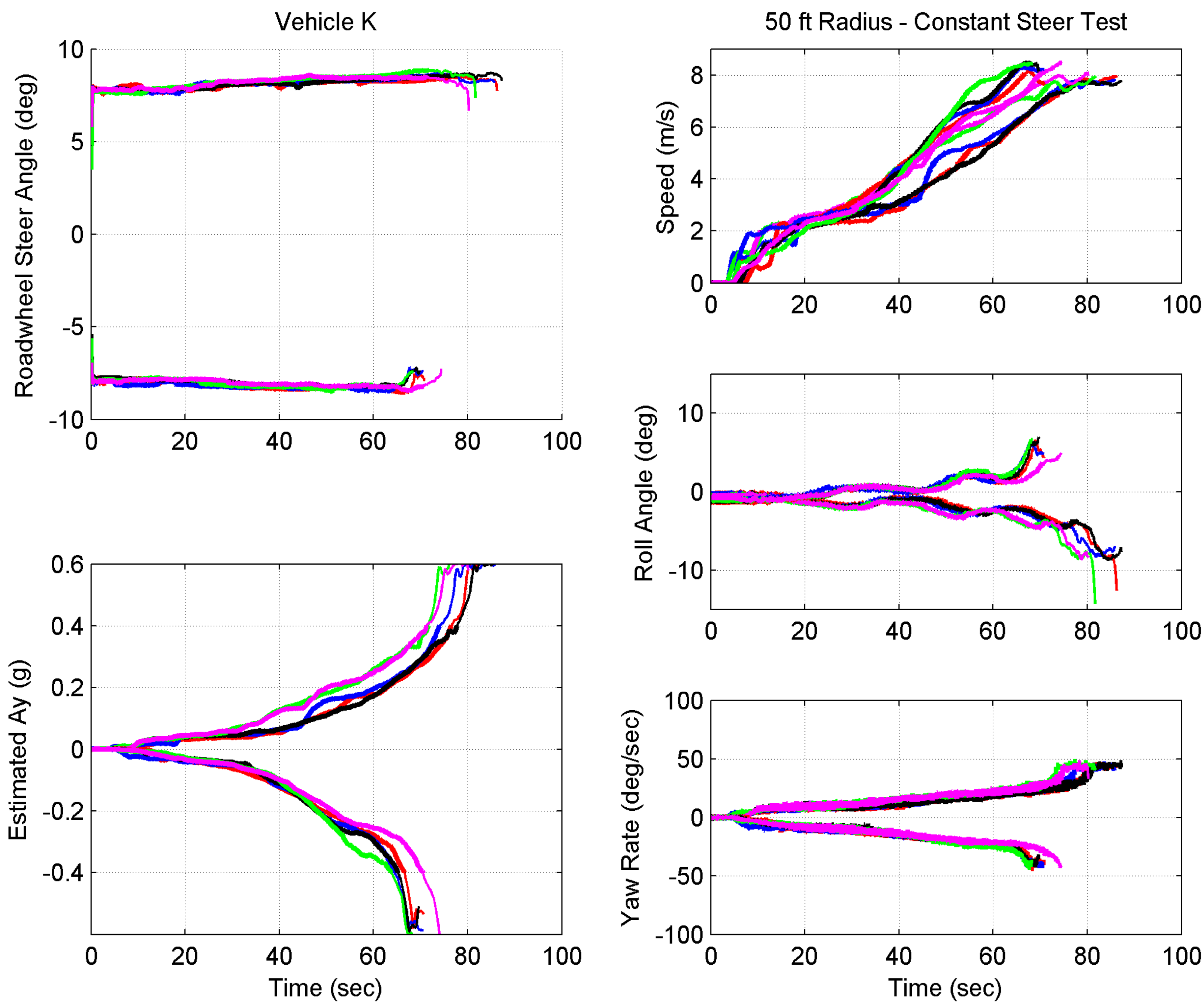
0.538

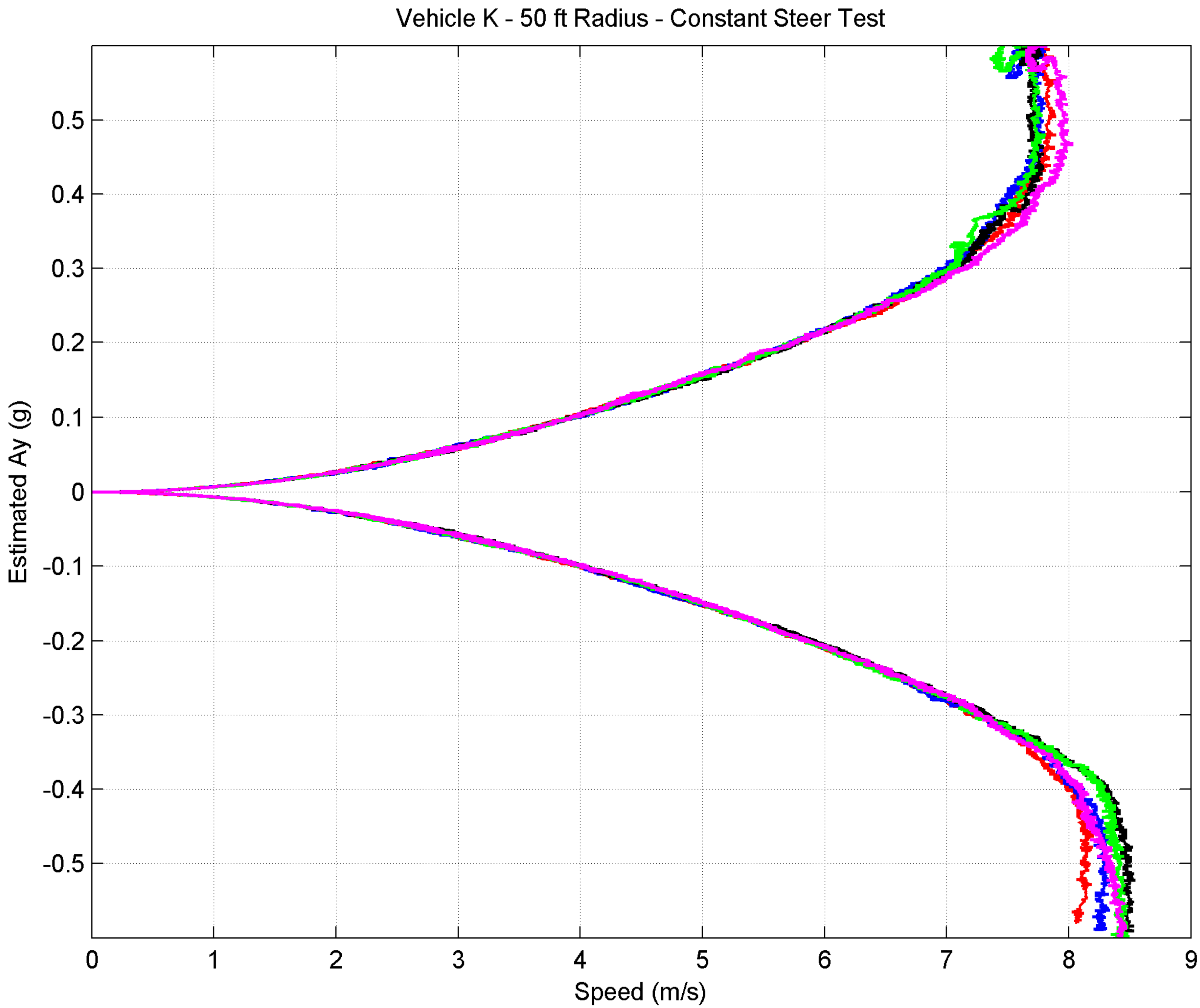
Threshold Ay

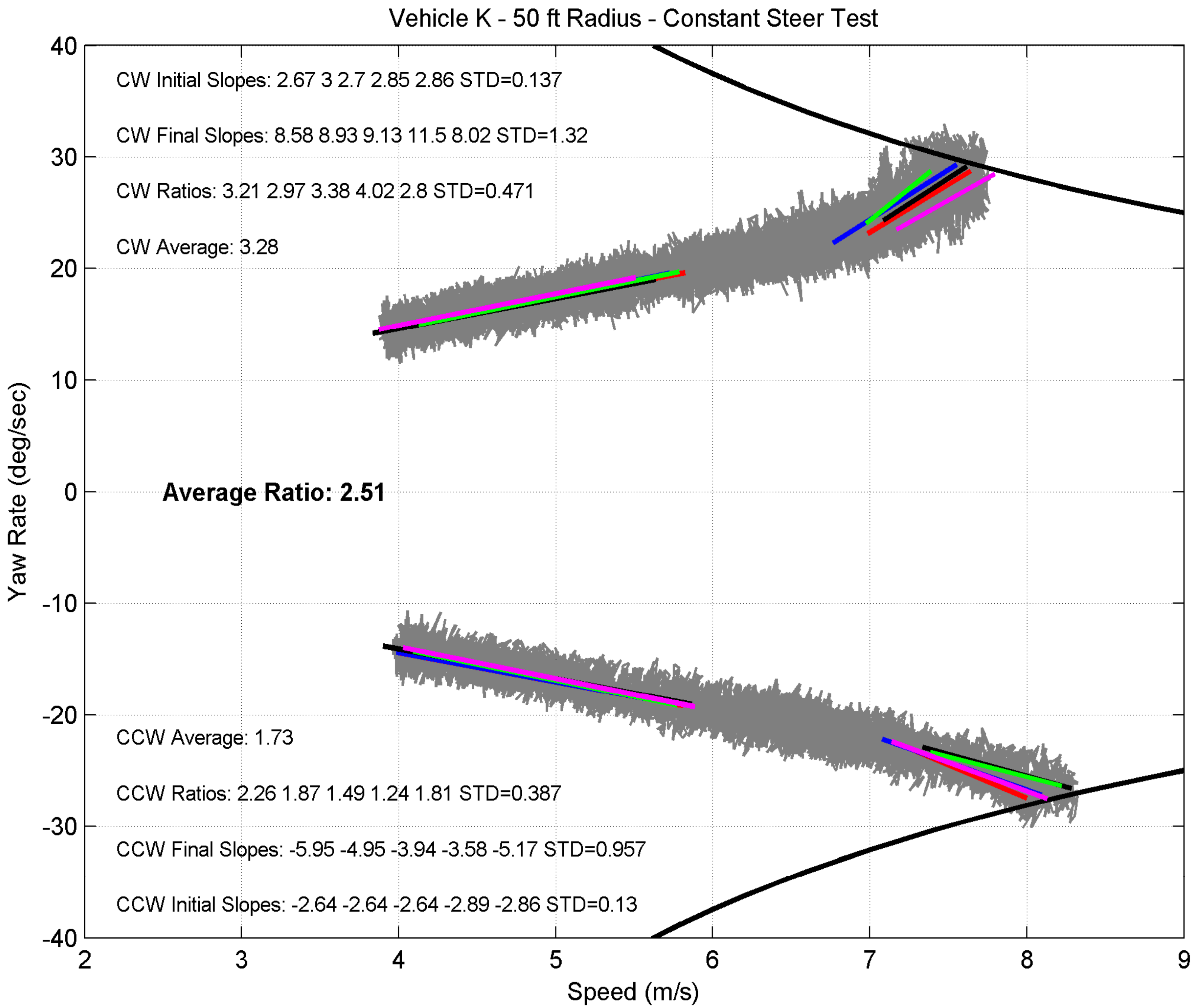


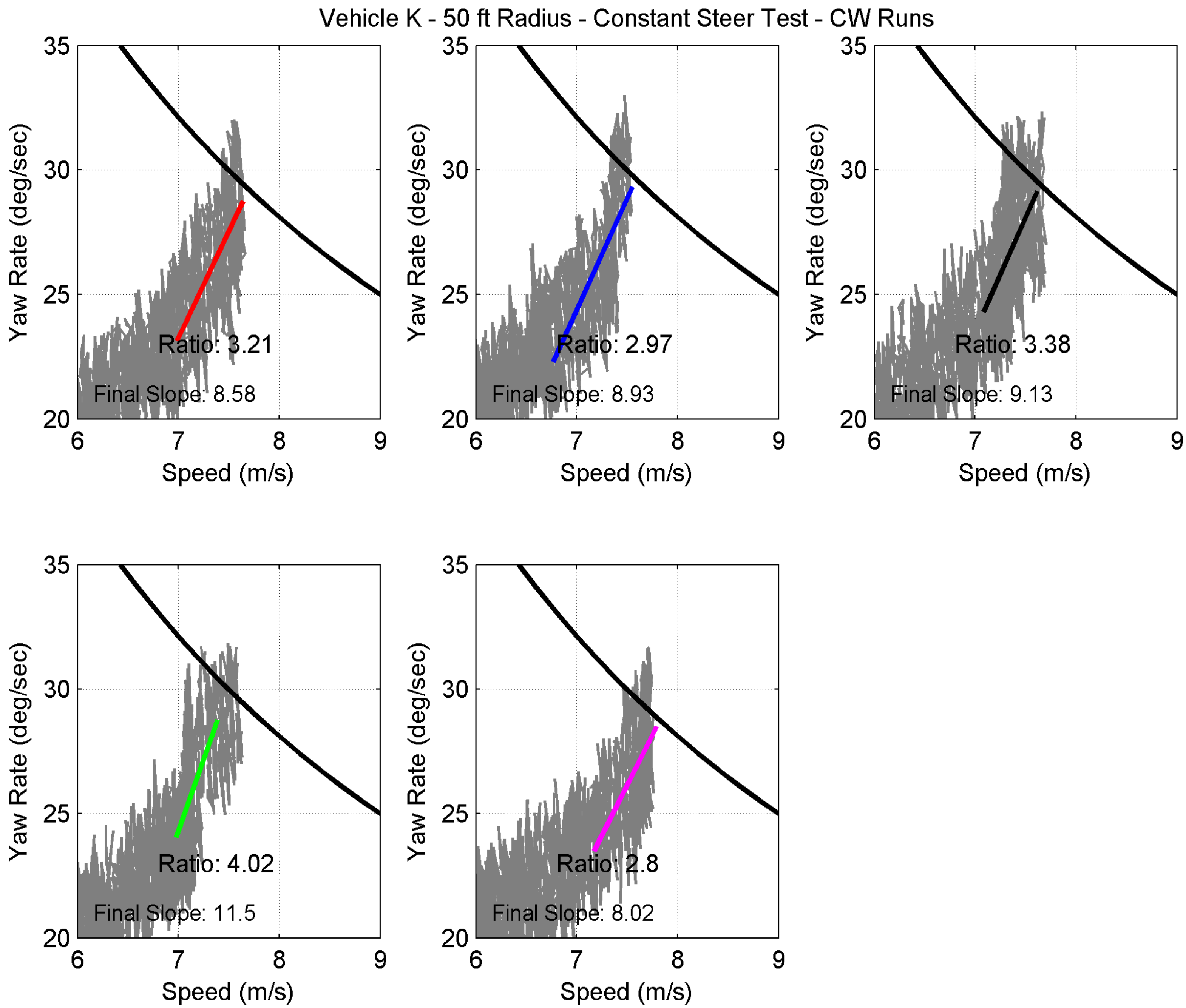
Vehicle K - SIS
Roadwheel Steer (deg)
10
5
0
-5
-10
0
2
4
6
8
10
Speed (mph)
25
20
15
10
Right Turn
Left Turn
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Time (sec)
Roll Angle (deg)
10
0
-10
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

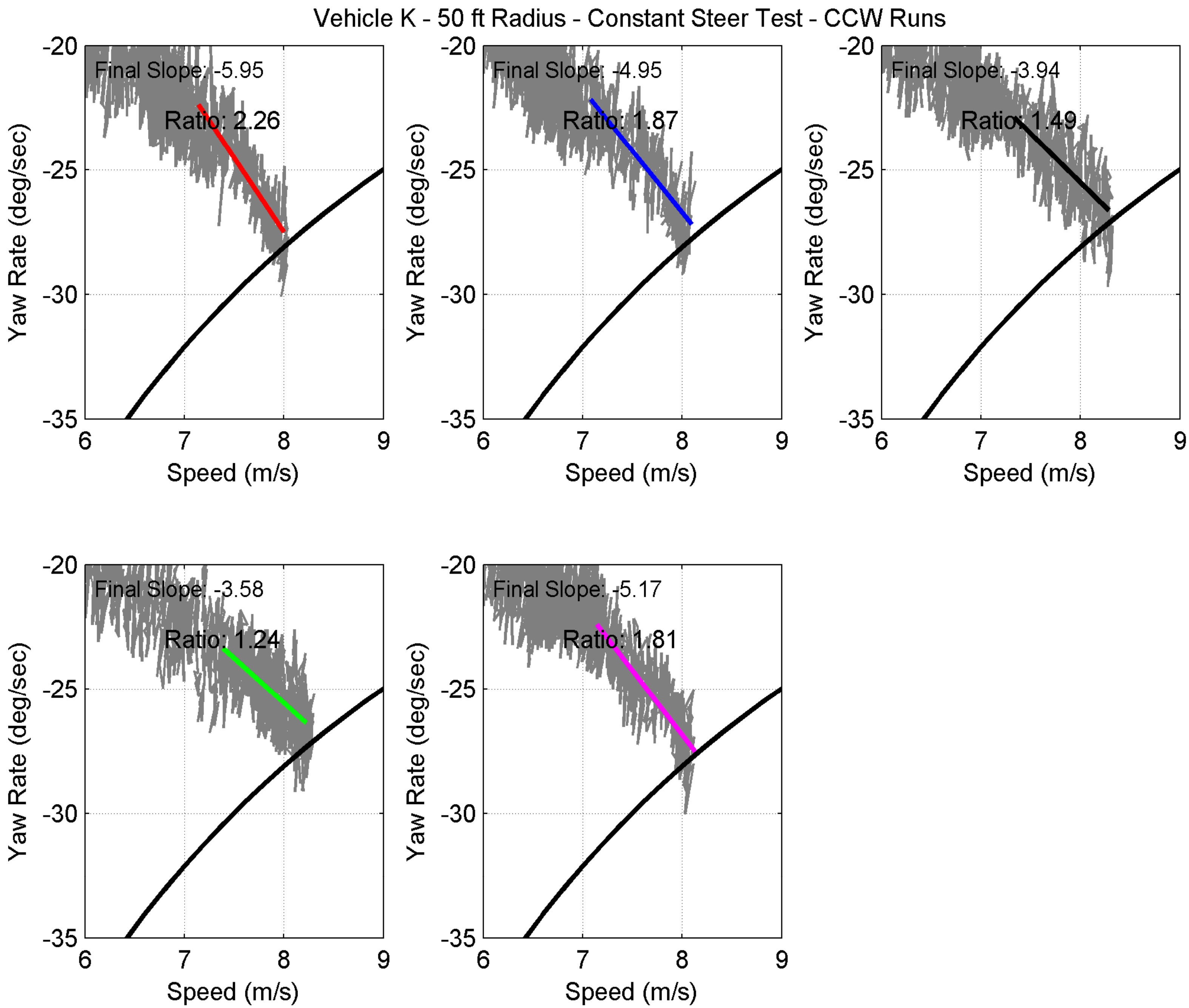

Vehicle K - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Roadwheel Steer Angle (deg)
10
5
0
-5
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)


Vehicle K
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

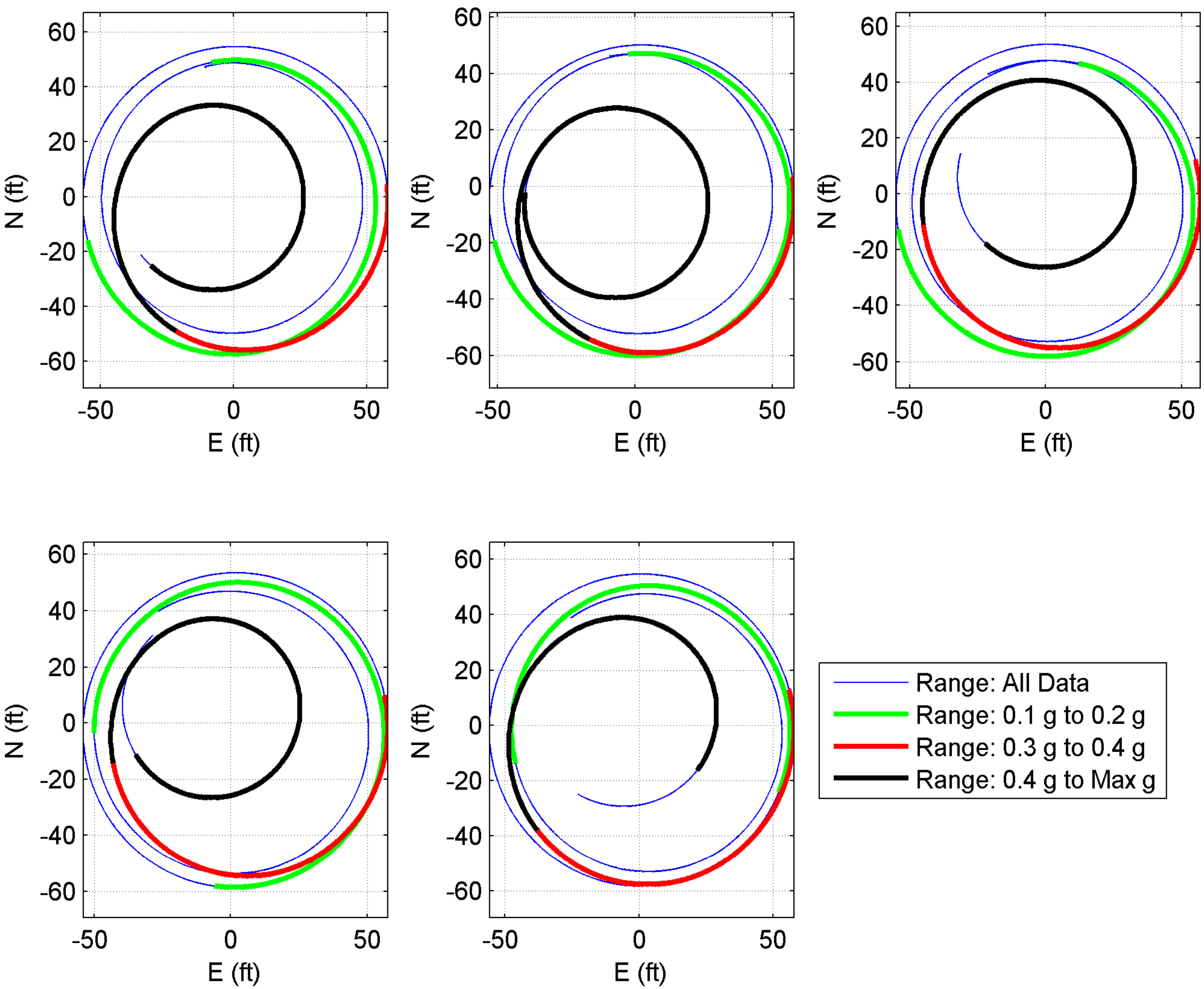

Vehicle K - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
Speed (m/s)


Vehicle K - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 2.67 3 2.7 2.85 2.86 STD=0.137
CW Final Slopes: 8.58 8.93 9.13 11.5 8.02 STD=1.32
CW Ratios: 3.21 2.97 3.38 4.02 2.8 STD=0.471
CW Average: 3.28
Average Ratio: 2.51
CCW Average: 1.73
CCW Ratios: 2.26 1.87 1.49 1.24 1.81 STD=0.387
CCW Final Slopes: -5.95 -4.95 -3.94 -3.58 -5.17 STD=0.957
CCW Initial Slopes: -2.64 -2.64 -2.64 -2.89 -2.86 STD=0.13
Yaw Rate (deg/sec)
Speed (m/s)
40
30
20
10
0
-10
-20
-30
-40
2
3
4
5
6
7
8
9

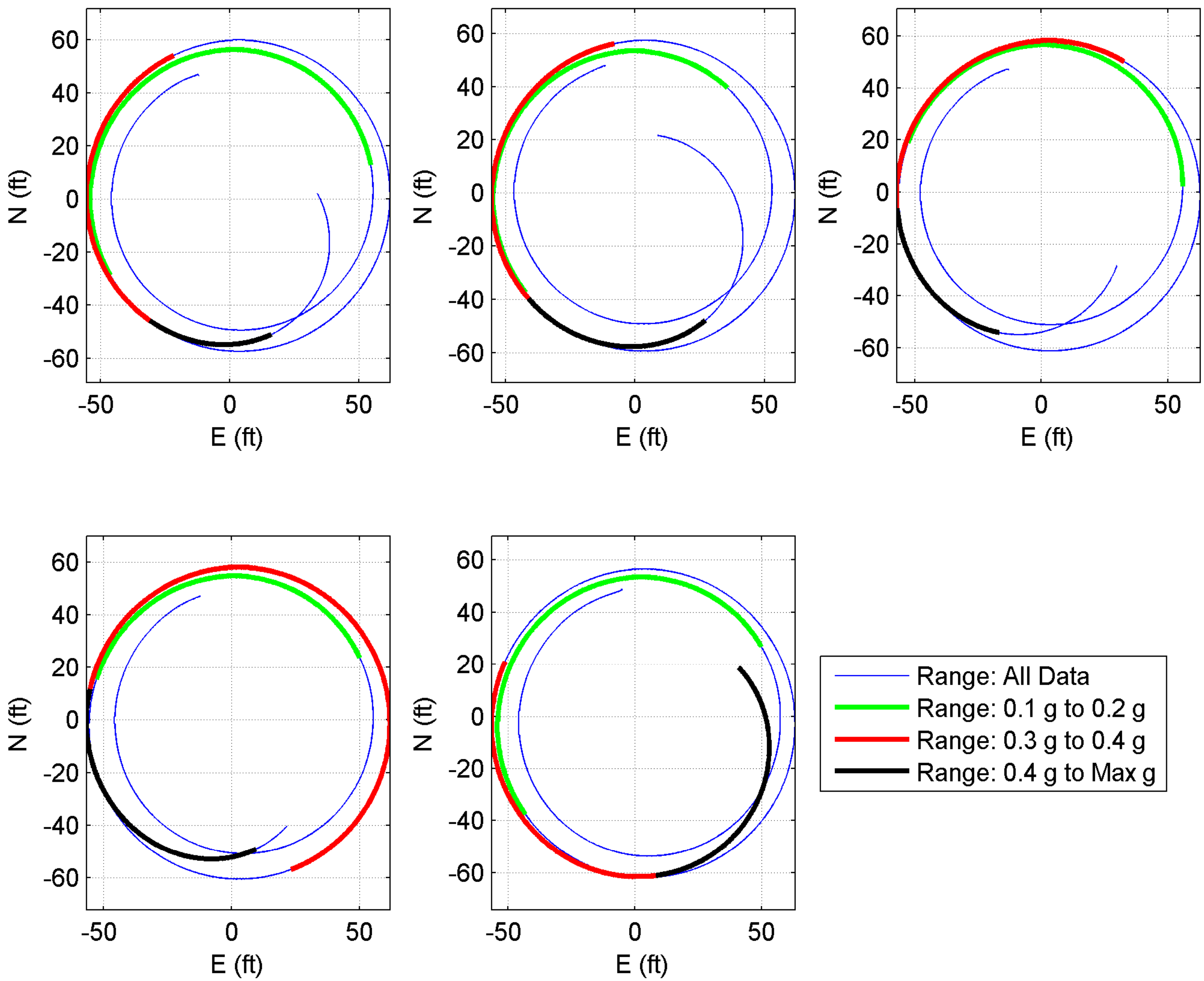

Vehicle K - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 3.21
Final Slope: 8.58
Ratio: 2.97
Final Slope: 8.93
Ratio: 3.38
Final Slope: 9.13
Ratio: 4.02
Final Slope: 11.5
Ratio: 2.8
Final Slope: 8.02

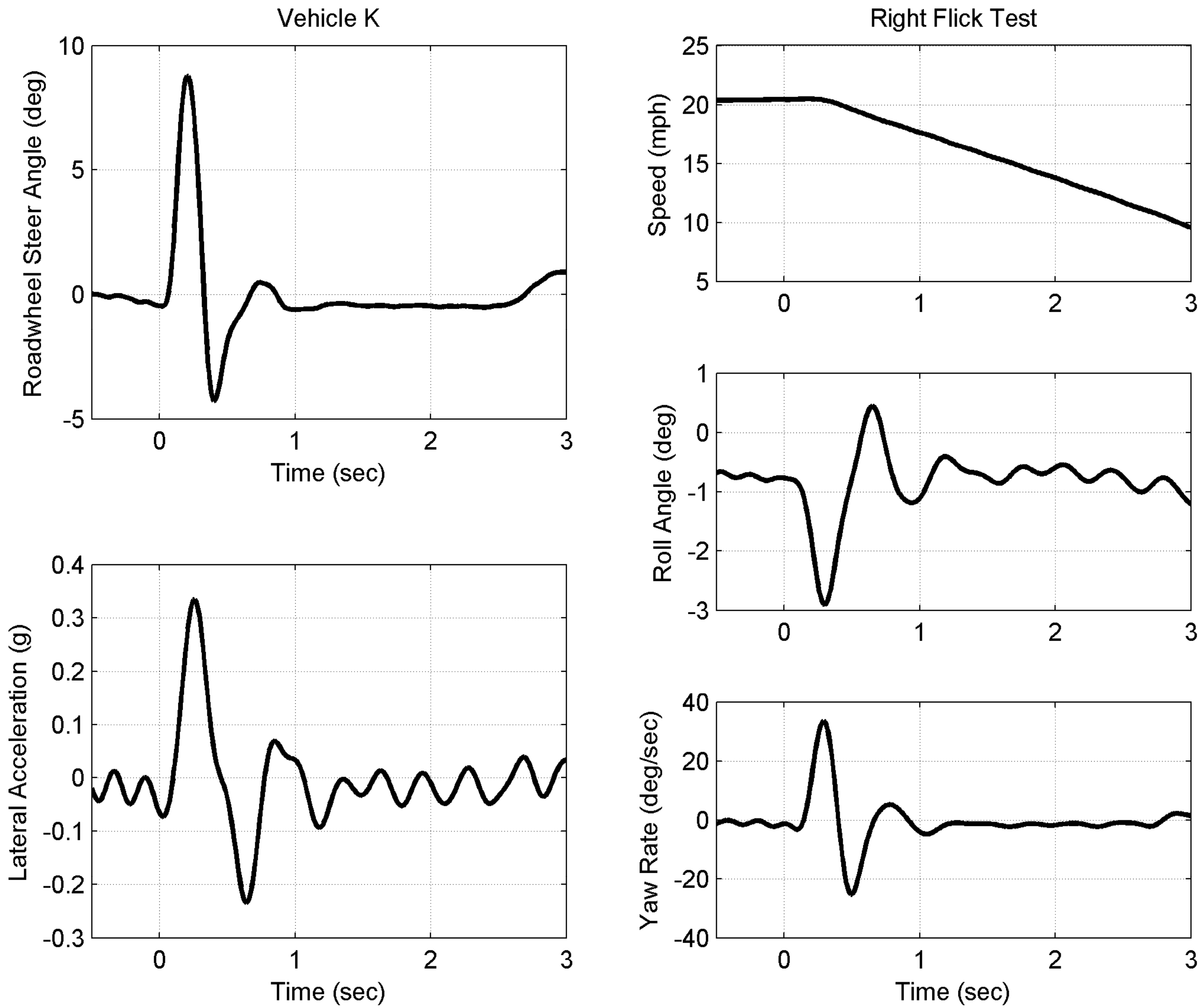

Vehicle K - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -5.95
Ratio: 2.26
Final Slope: -4.95
Ratio: 1.87
Final Slope: -3.94
Ratio: 1.49
Final Slope: -3.58
Ratio: 1.24
Final Slope: -5.17
Ratio: 1.81
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

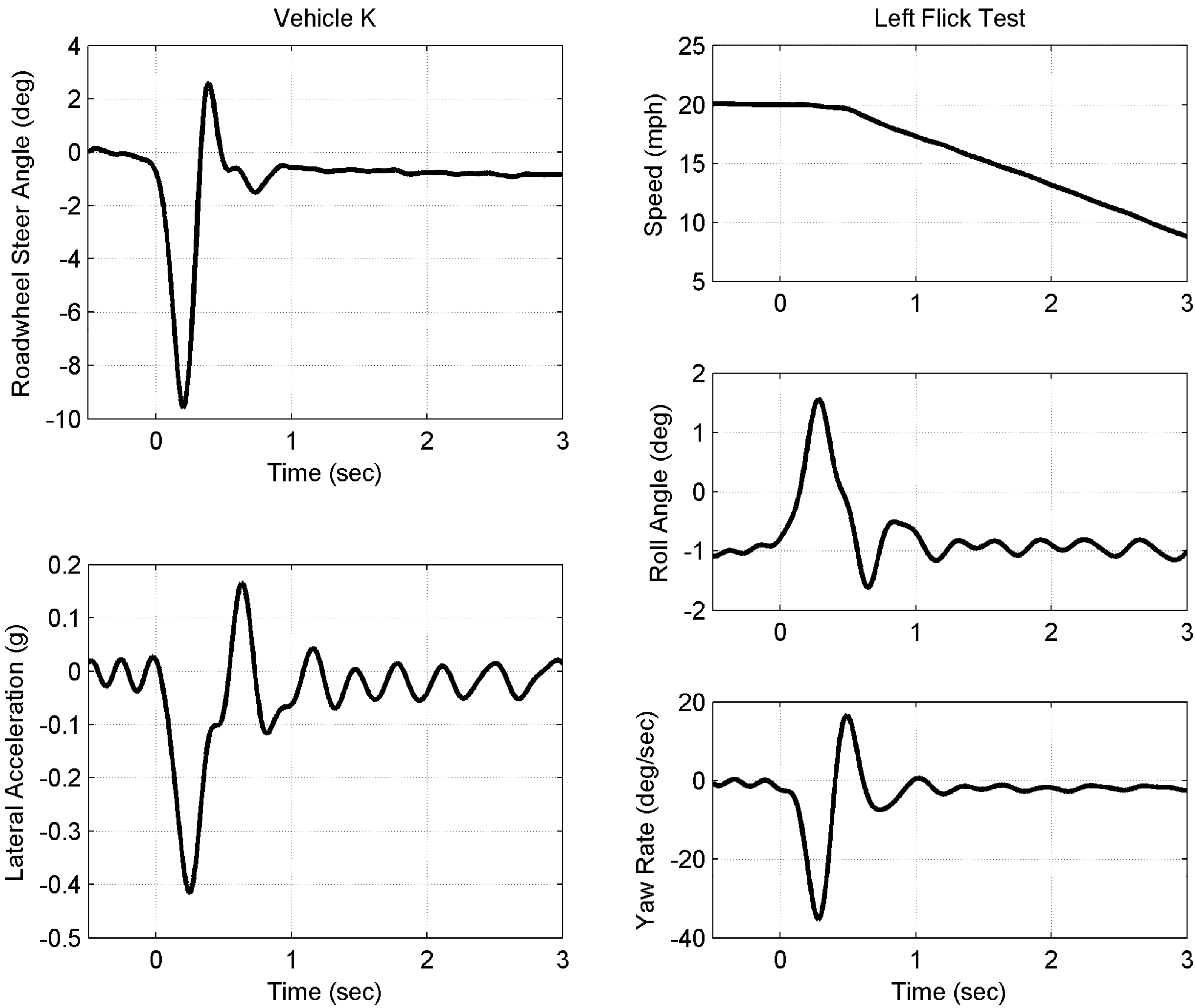
Vehicle K - 50 ft Radius - Constant Steer Test - CW Runs



Vehicle K - 50 ft Radius - Constant Steer Test - CCW Runs

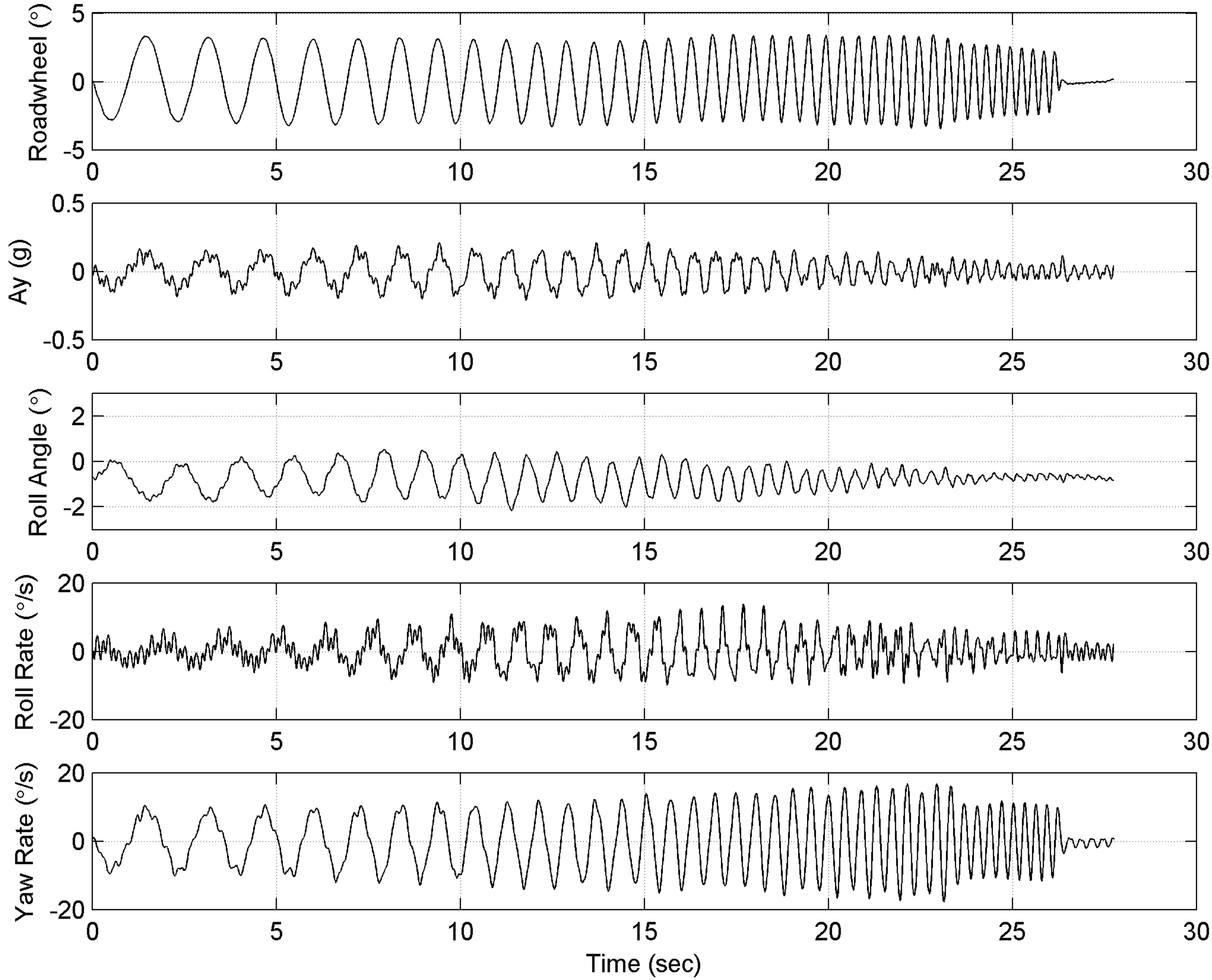


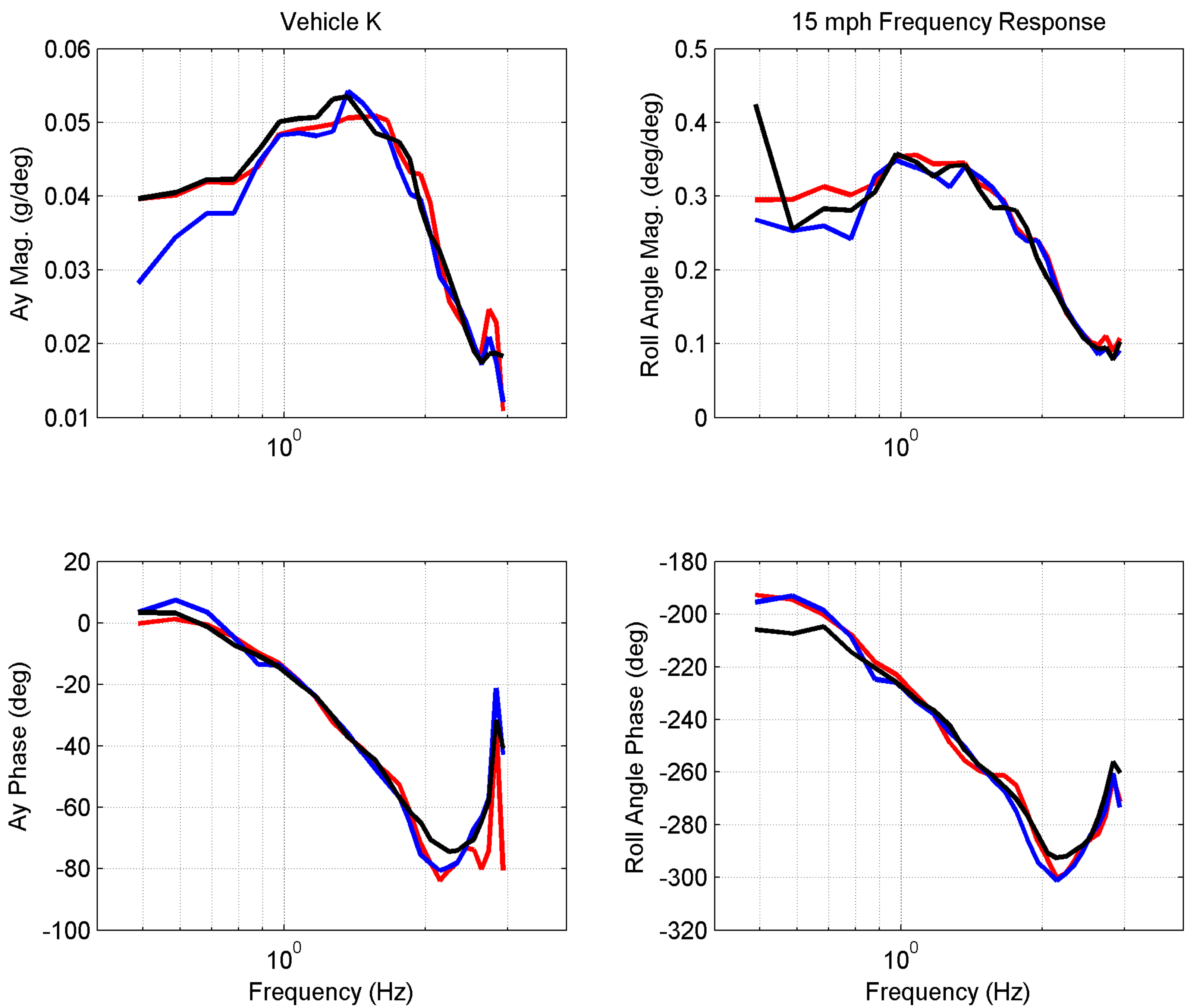

Vehicle K
Right Flick Test
Roadwheel Steer Angle (deg)
10
5
0
-5
Time (sec)
0
1
2
3
Speed (mph)
25
20
15
10
5
Roll Angle (deg)
1
0
-1
-2
-3
Lateral Acceleration (g)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
Yaw Rate (deg/sec)
40
20
0
-20
-40



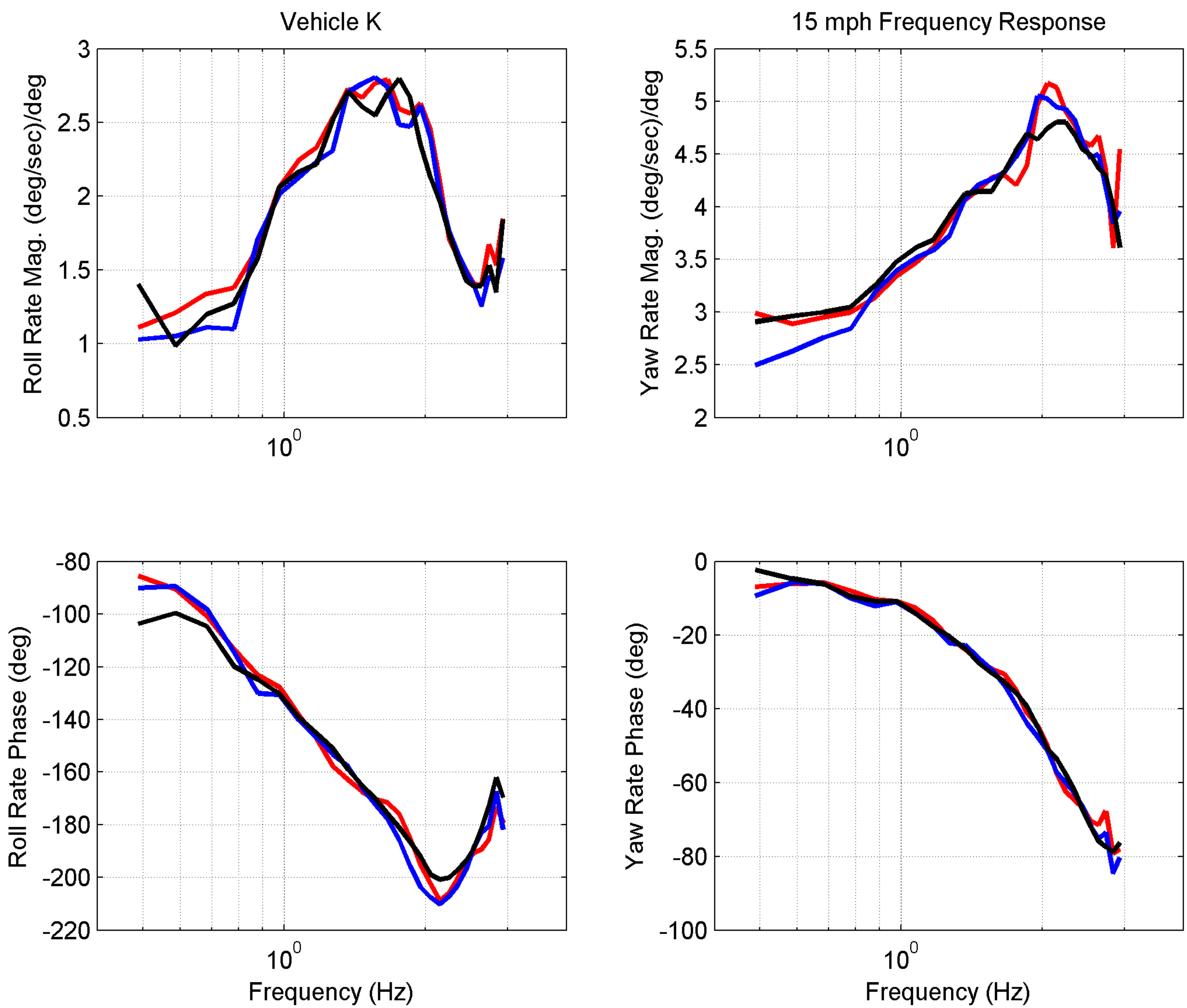
Vehicle K
Left Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

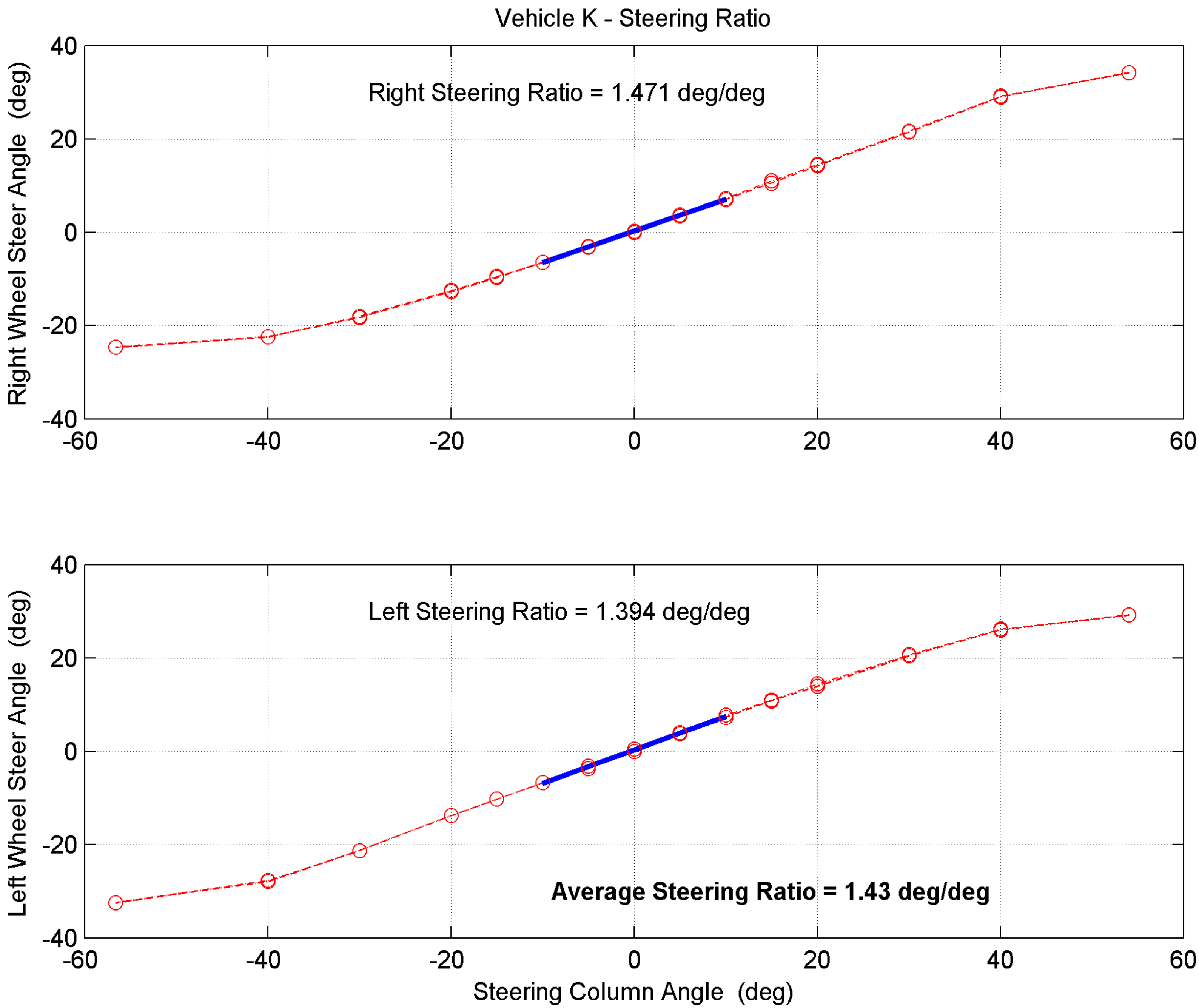
Representative Sine Sweep Time Domain Plots - Vehicle K



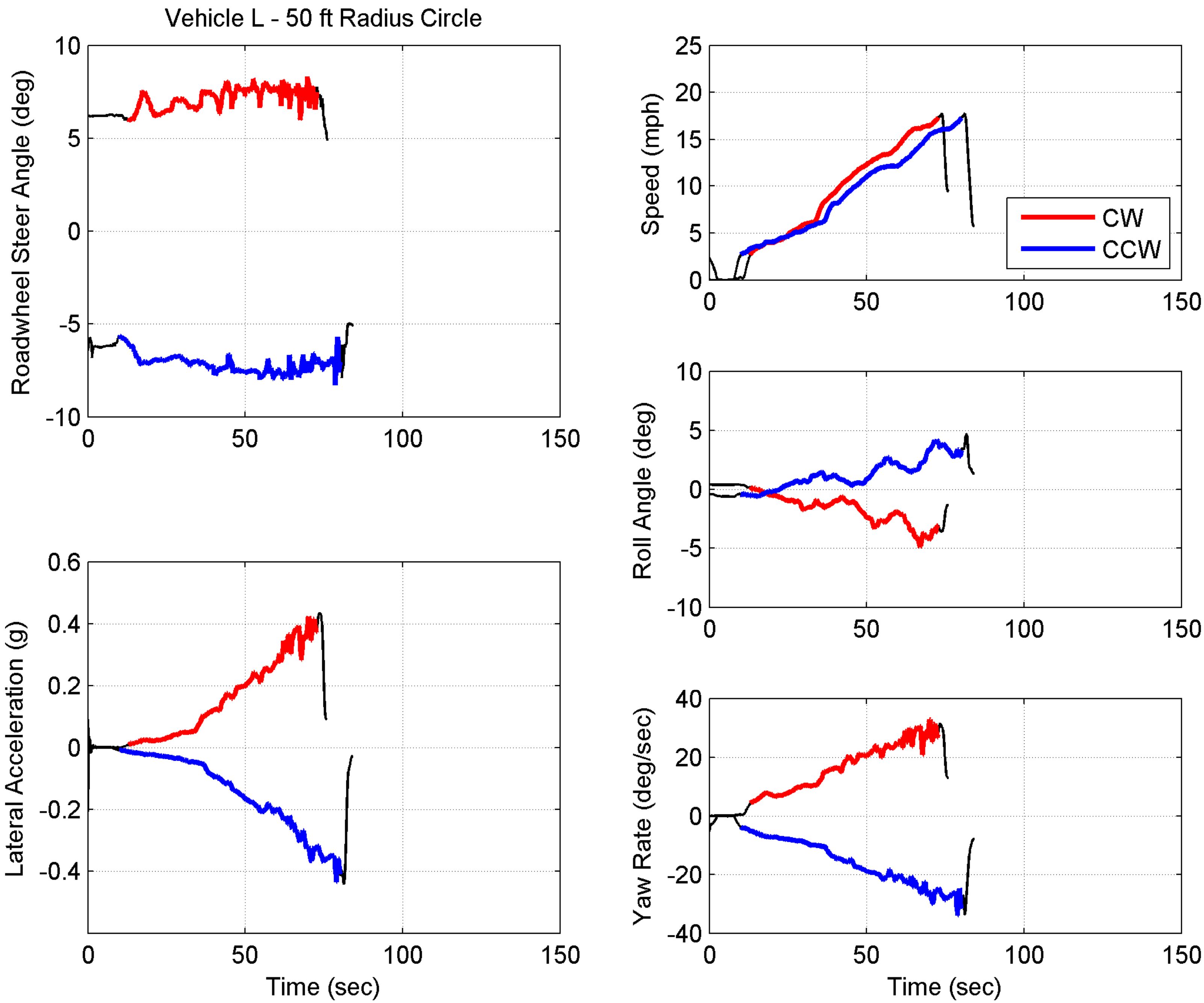


Vehicle K
15 mph Frequency Response
Ay Mag. (g/deg)
0.06
0.05
0.04
0.03
0.02
0.01
10^0
Roll Angle Mag. (deg/deg)
0.5
0.4
0.3
0.2
0.1
0
10^0
Ay Phase (deg)
20
0
-20
-40
-60
-80
-100
10^0
Frequency (Hz)
Roll Angle Phase (deg)
-180
-200
-220
-240
-260
-280
-300
-320
10^0
Frequency (Hz)

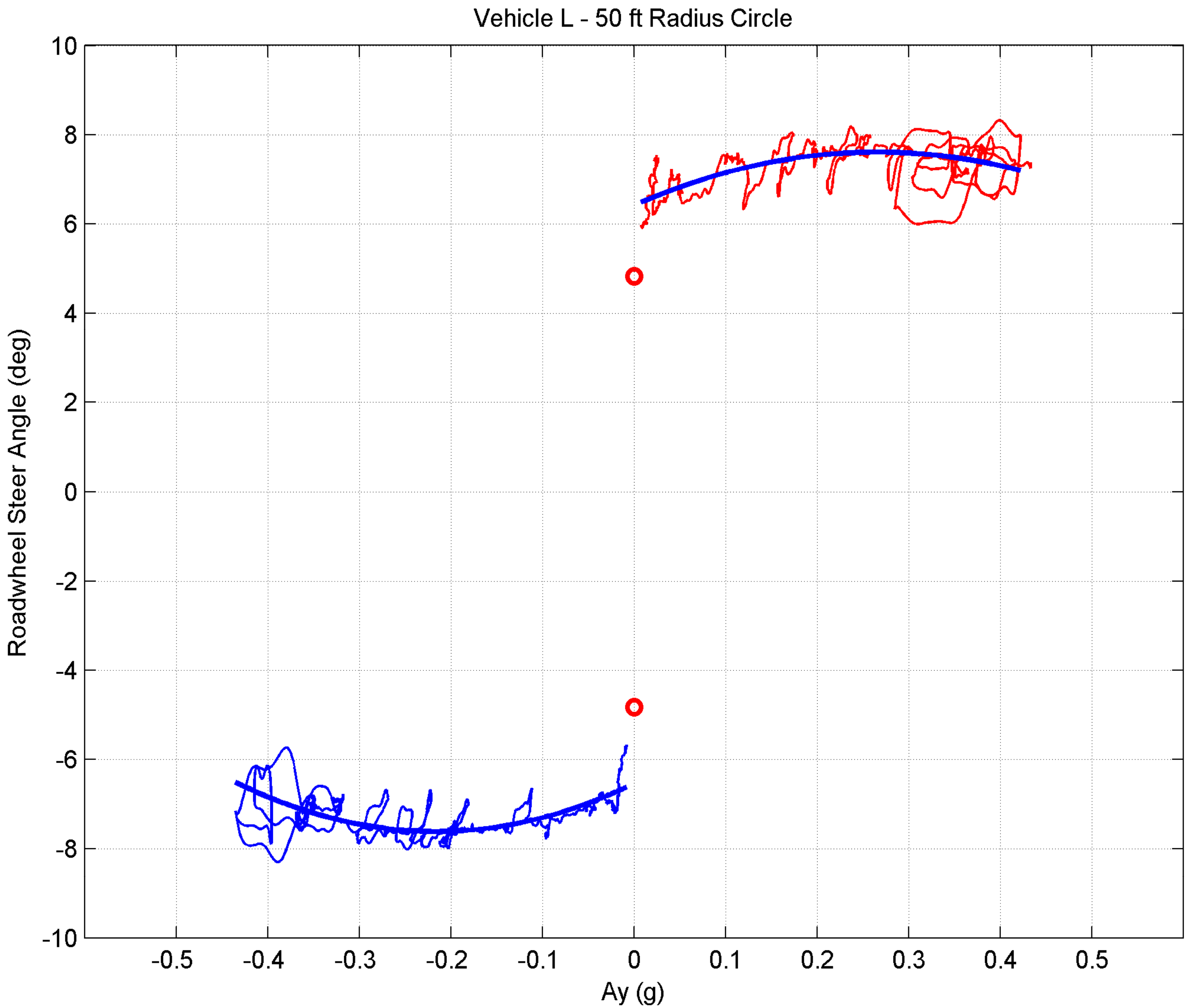

Vehicle K
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
10^0
3
2.5
2
1.5
1
0.5
5.5
5
4.5
4
3.5
3
2.5
2
-80
-100
-120
-140
-160
-180
-200
-220
0
-20
-40
-60
-80
-100



Vehicle K - Steering Ratio
Right Steering Ratio = 1.471 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-60
-40
-20
0
20
40
60
Left Steering Ratio = 1.394 deg/deg
Average Steering Ratio = 1.43 deg/deg
Left Wheel Steer Angle (deg)
40
20
0
-20
-40
-60
-40
-20
0
20
40
60
Steering Column Angle (deg)

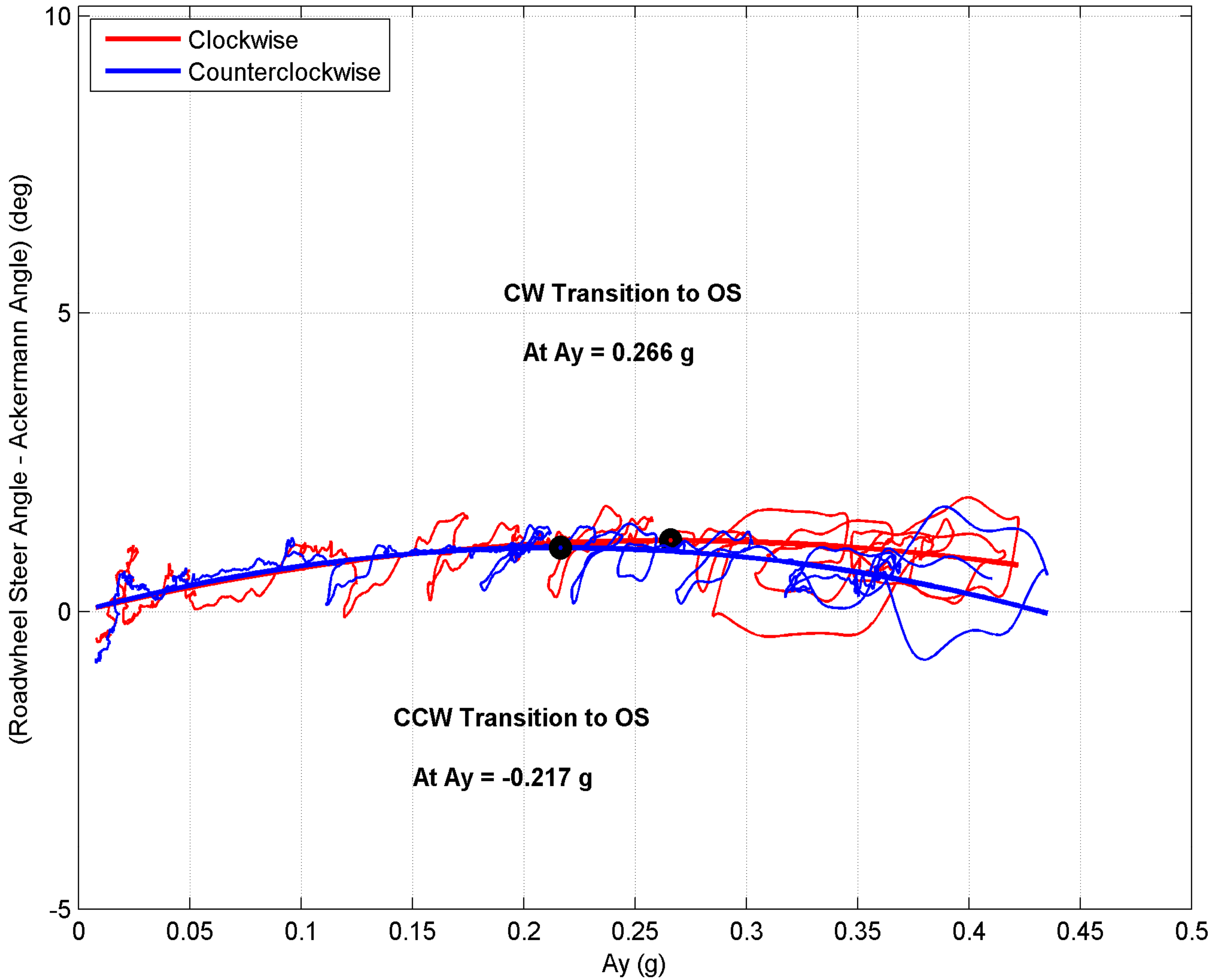


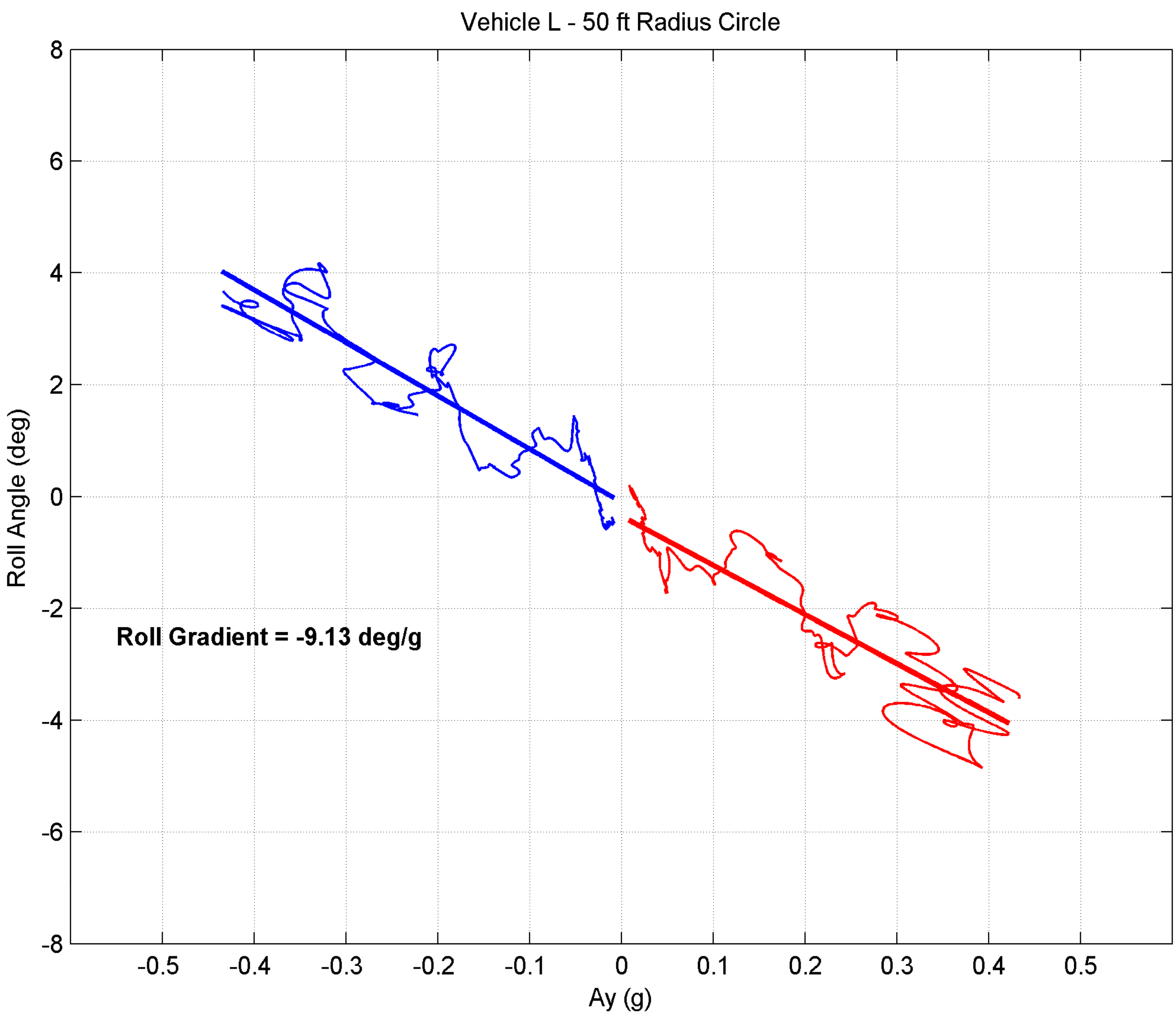
Vehicle L - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
5
0
-5
-10
0
50
100
150
Speed (mph)
25
20
15
10
5
0
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Time (sec)
Yaw Rate (deg/sec)
40
20
-20
-40



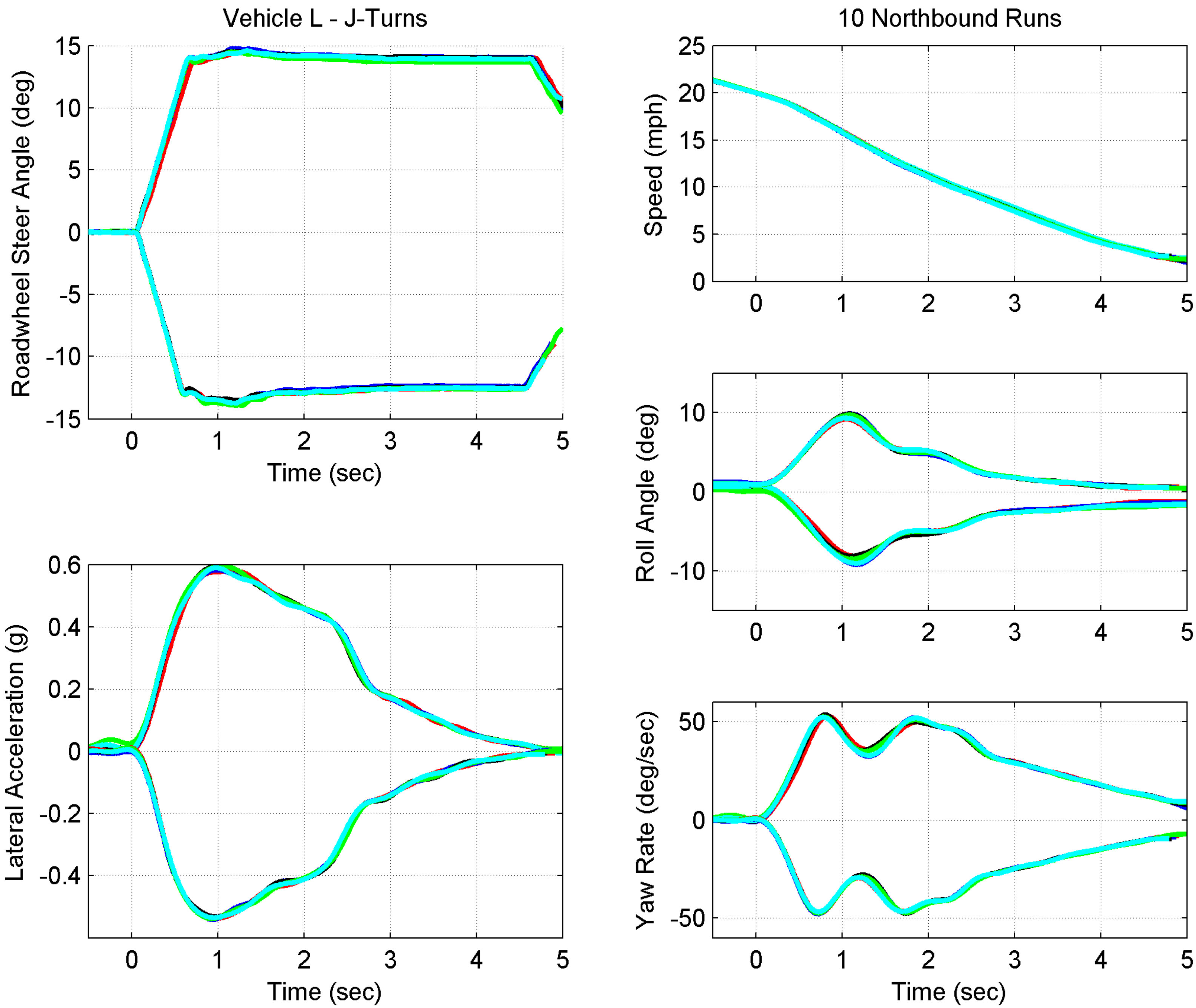
Vehicle L - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

Vehicle L - 50 ft Radius Circle

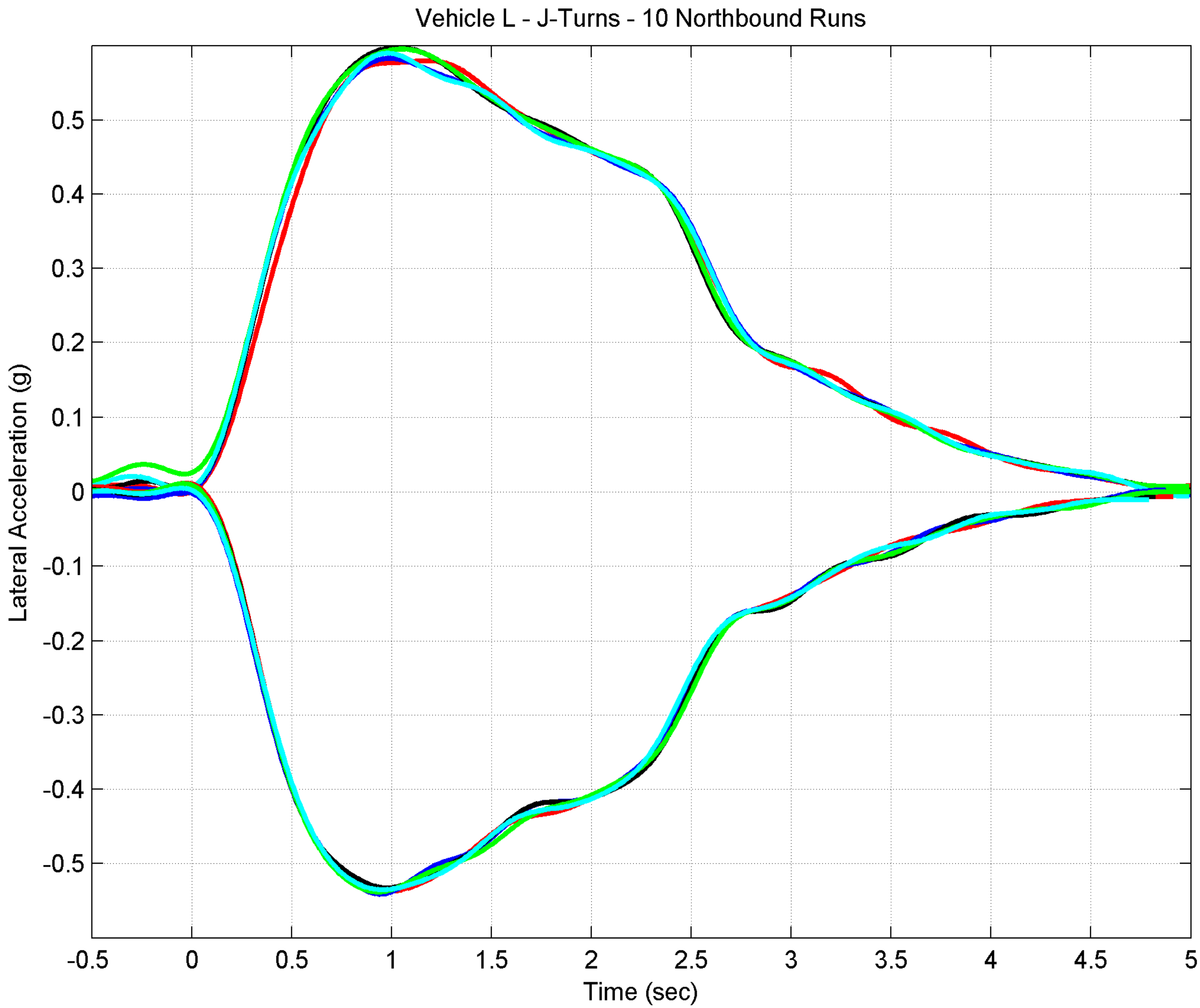




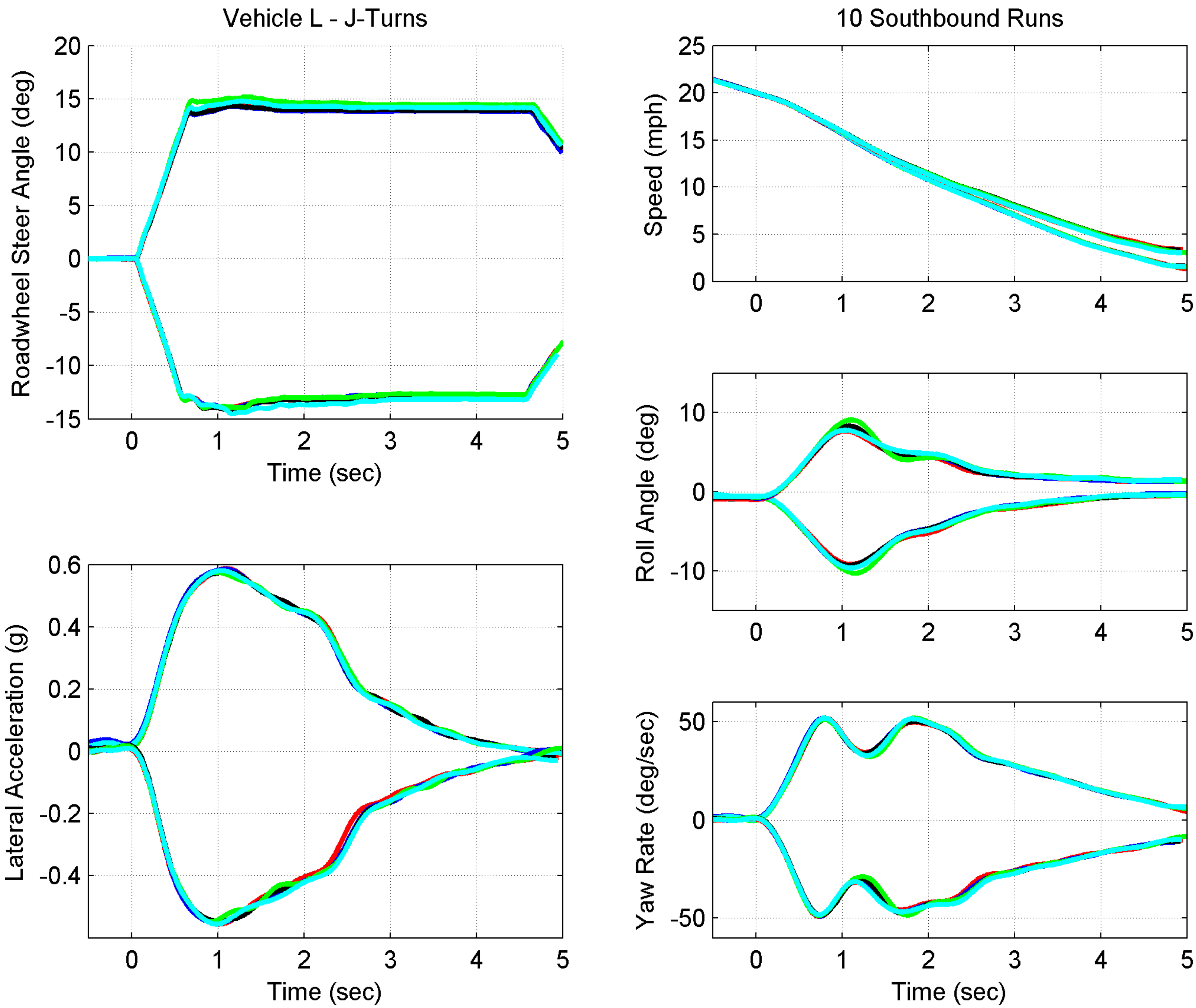
Vehicle L - 50 ft Radius Circle
Roll Angle (deg)
8
6
4
2
0
-2
-4
-6
-8
Roll Gradient = -9.13 deg/g
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)



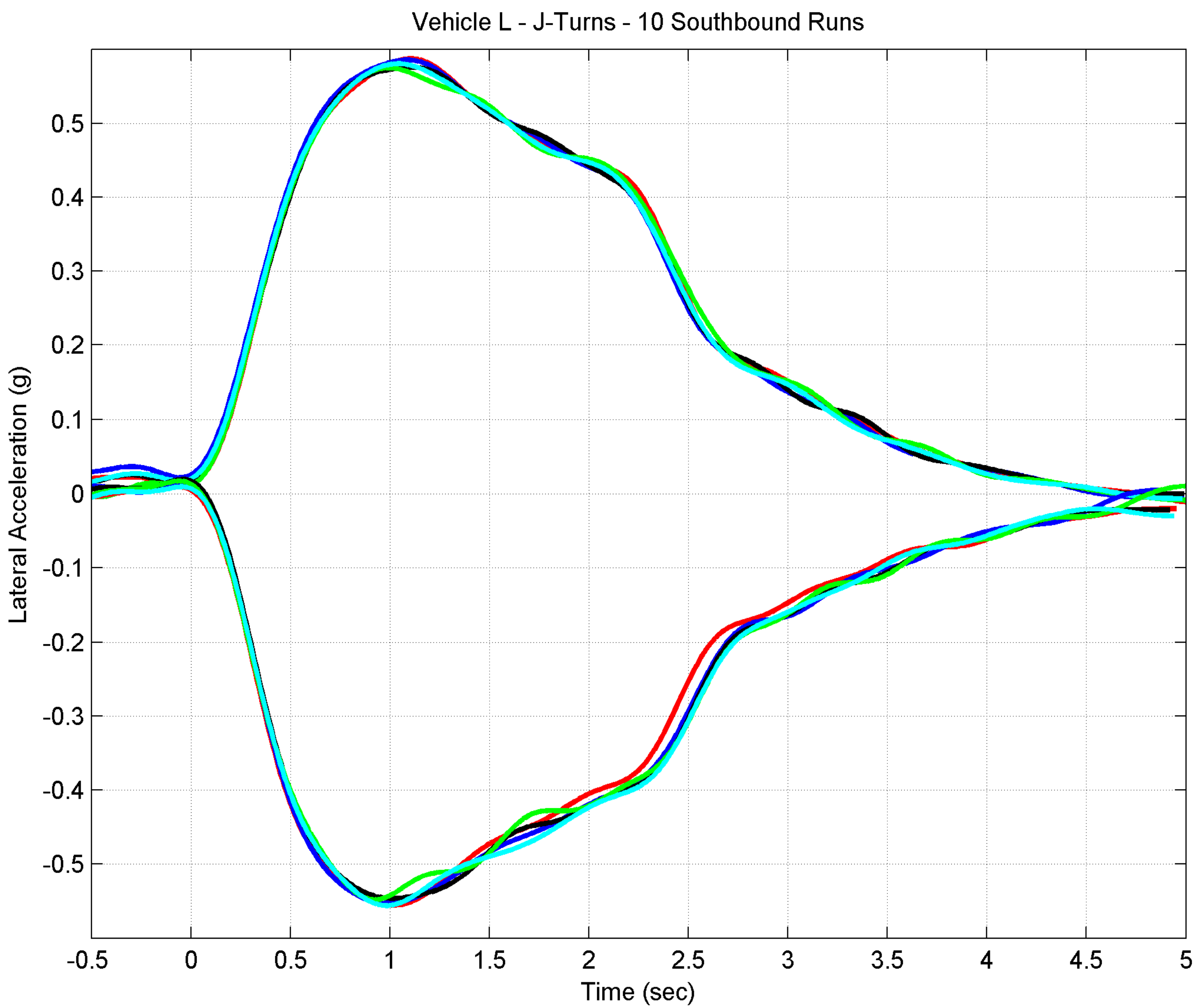
Vehicle L - J-Turns
10 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



Vehicle L - J-Turns - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle L - J-Turns
10 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)


Vehicle L - J-Turns - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle L

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.5795	-0.5383
2	0.5829	-0.5416
3	0.5972	-0.5331
4	0.5953	-0.5385
5	0.5898	-0.5355
Mean Value of 5 Runs	0.5889	-0.5374
Standard Deviation of 5 Runs	0.008	0.003

Average of 10 Northbound Runs

0.5632

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.5872	-0.5561
2	0.5855	-0.5532
3	0.5757	-0.5465
4	0.5748	-0.5485
5	0.5804	-0.5563
Mean Value of 5 Runs	0.5807	-0.5521
Standard Deviation of 5 Runs	0.006	0.004

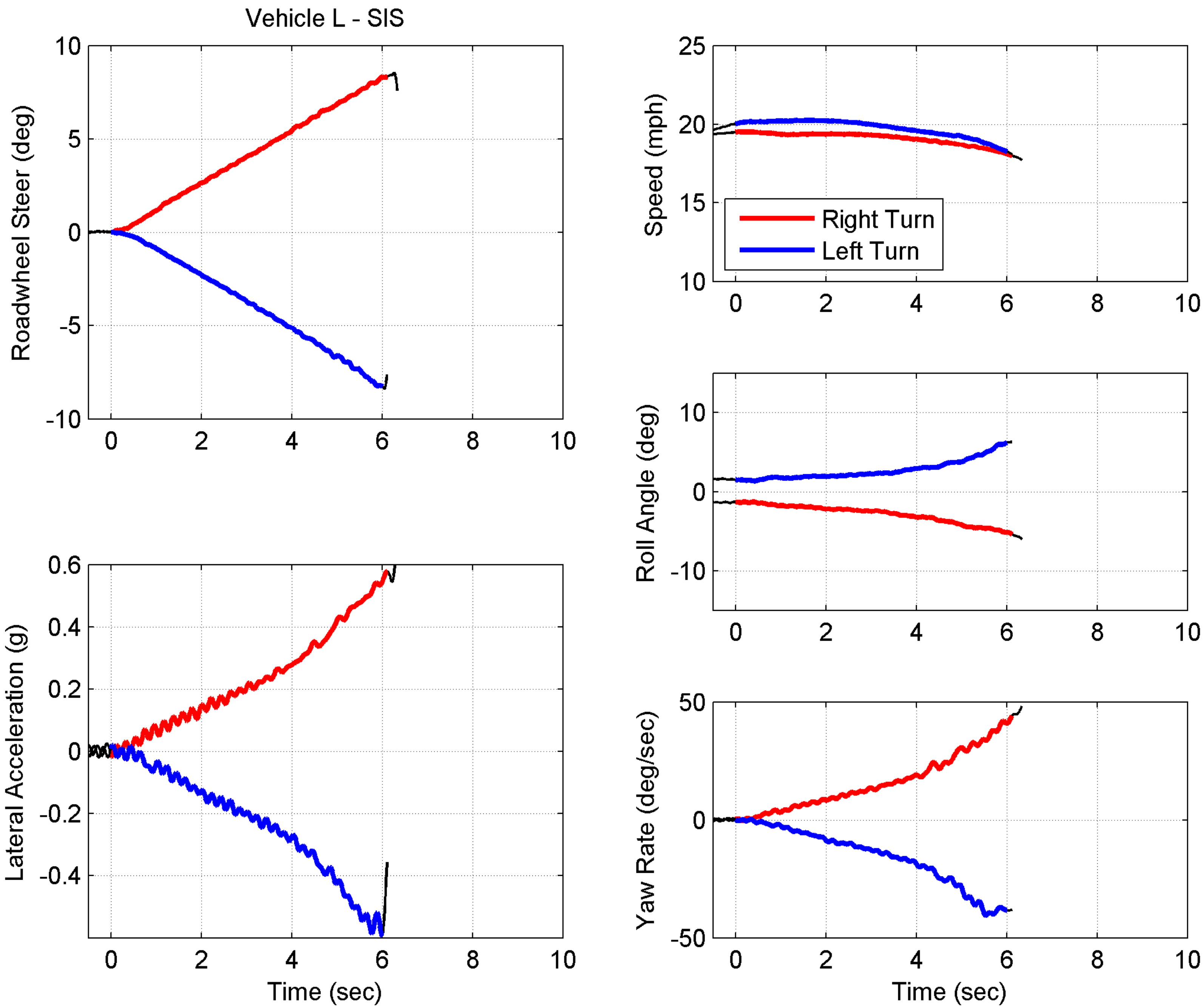
Average of 10 Southbound Runs

0.5664

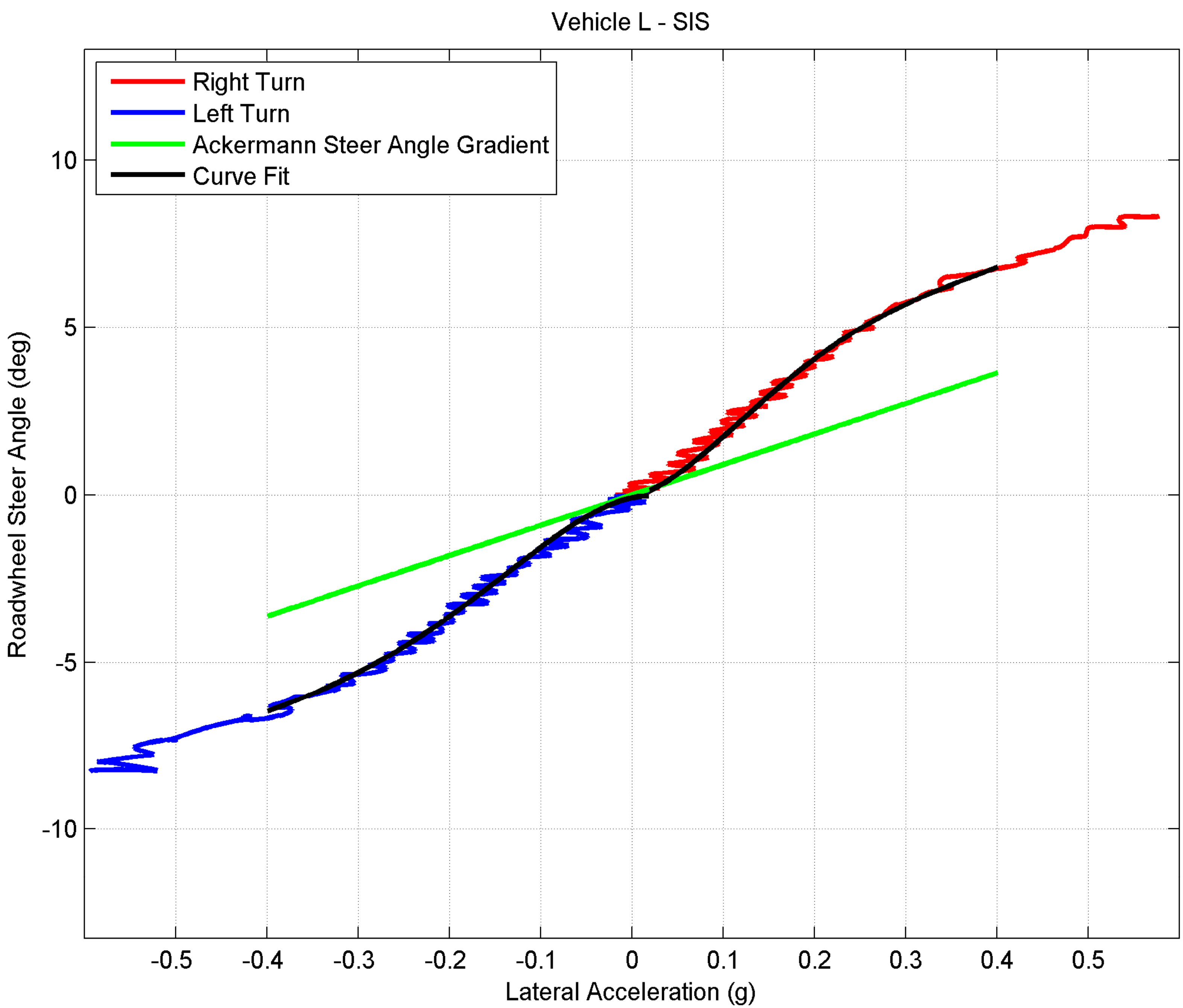
Average of All 20 Runs

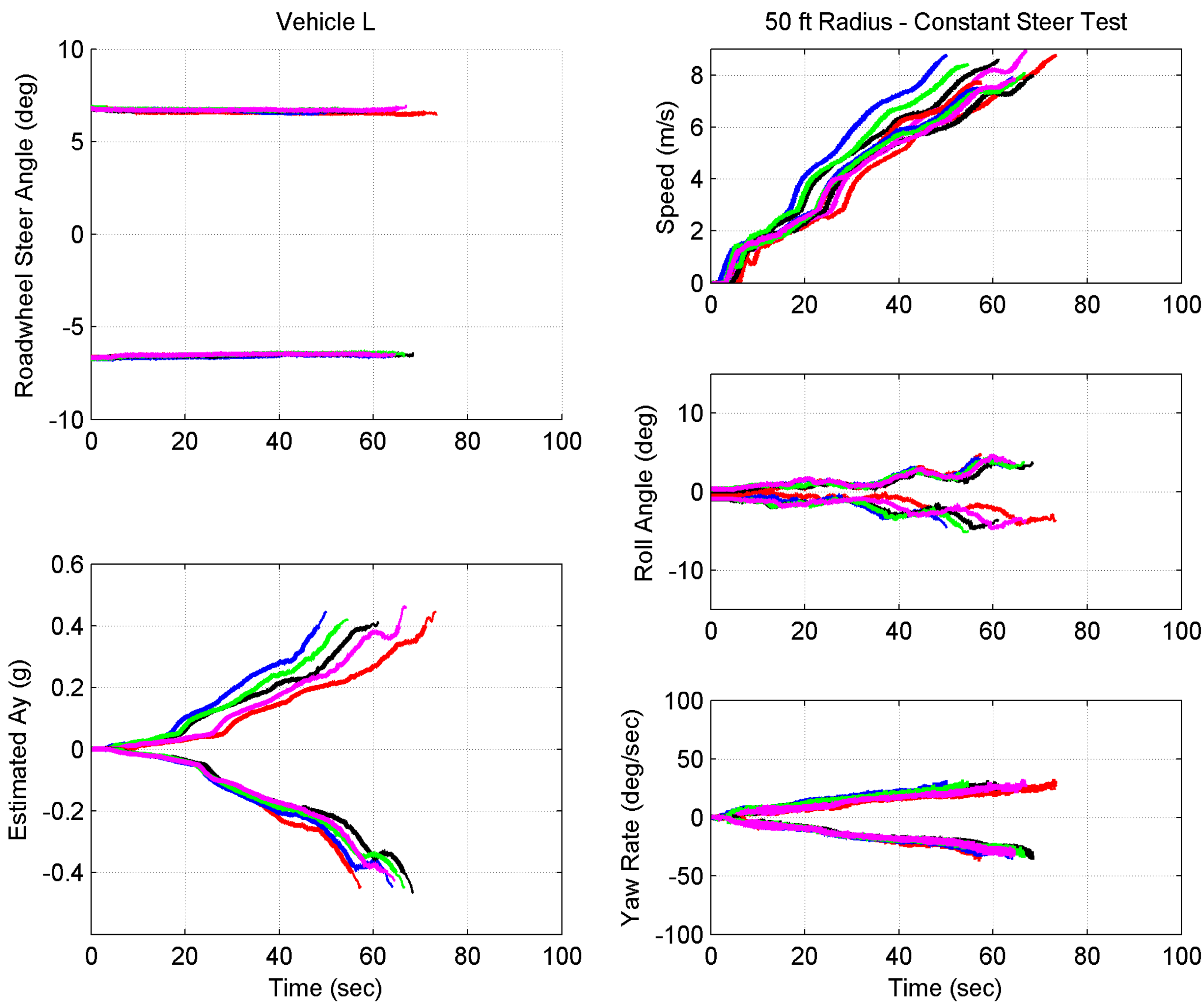
0.565

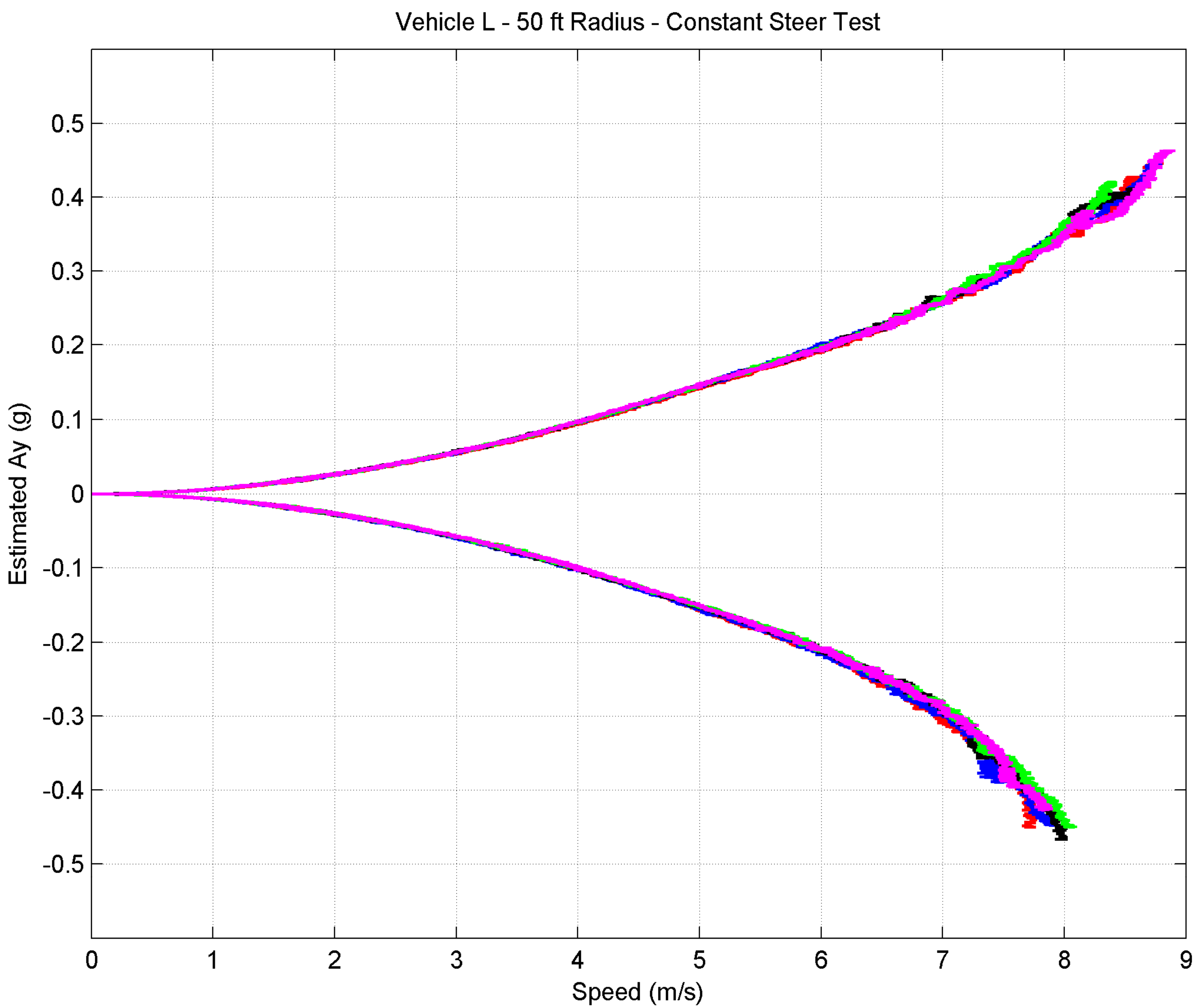
Threshold Ay

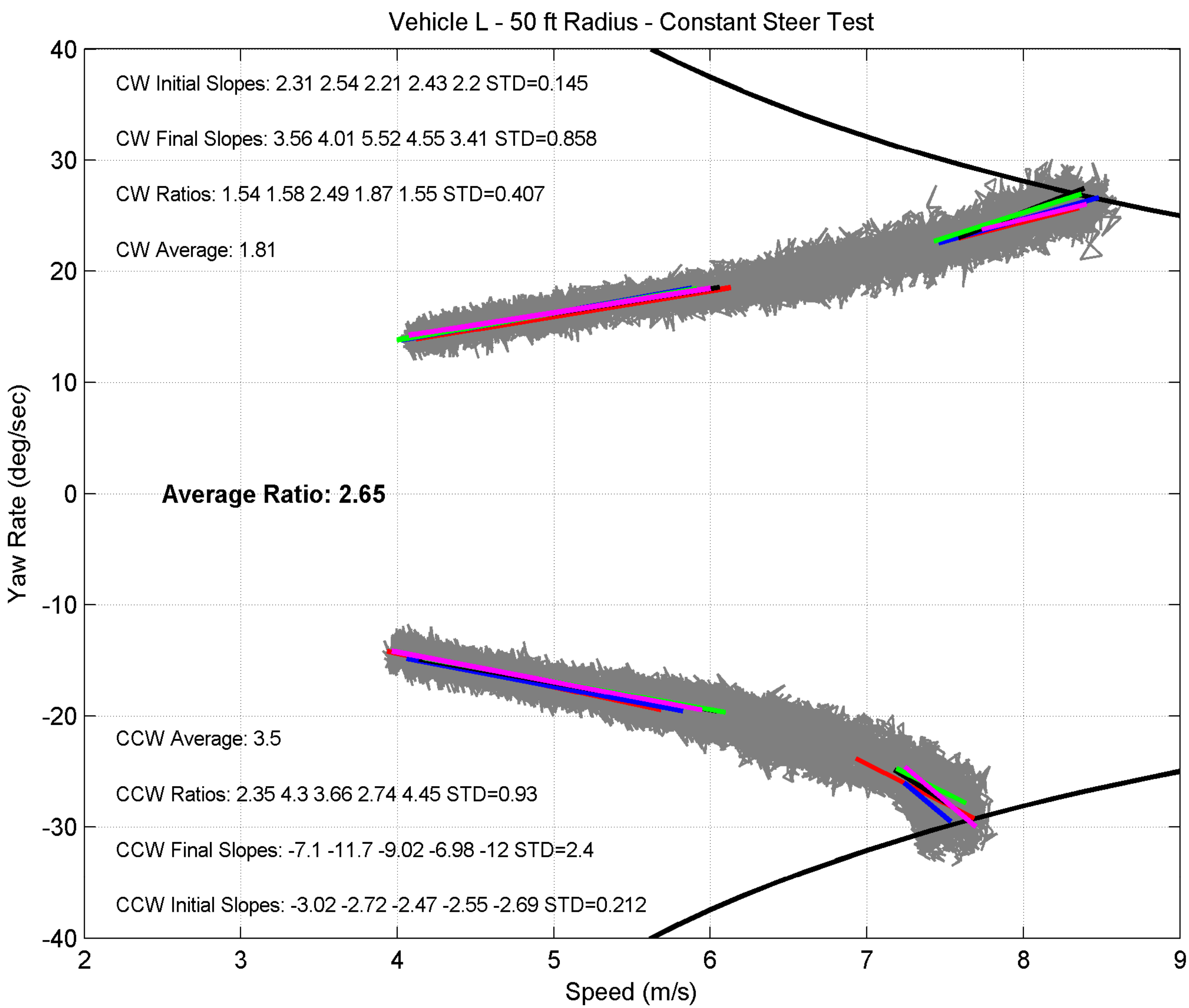


Vehicle L - SIS
Roadwheel Steer (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

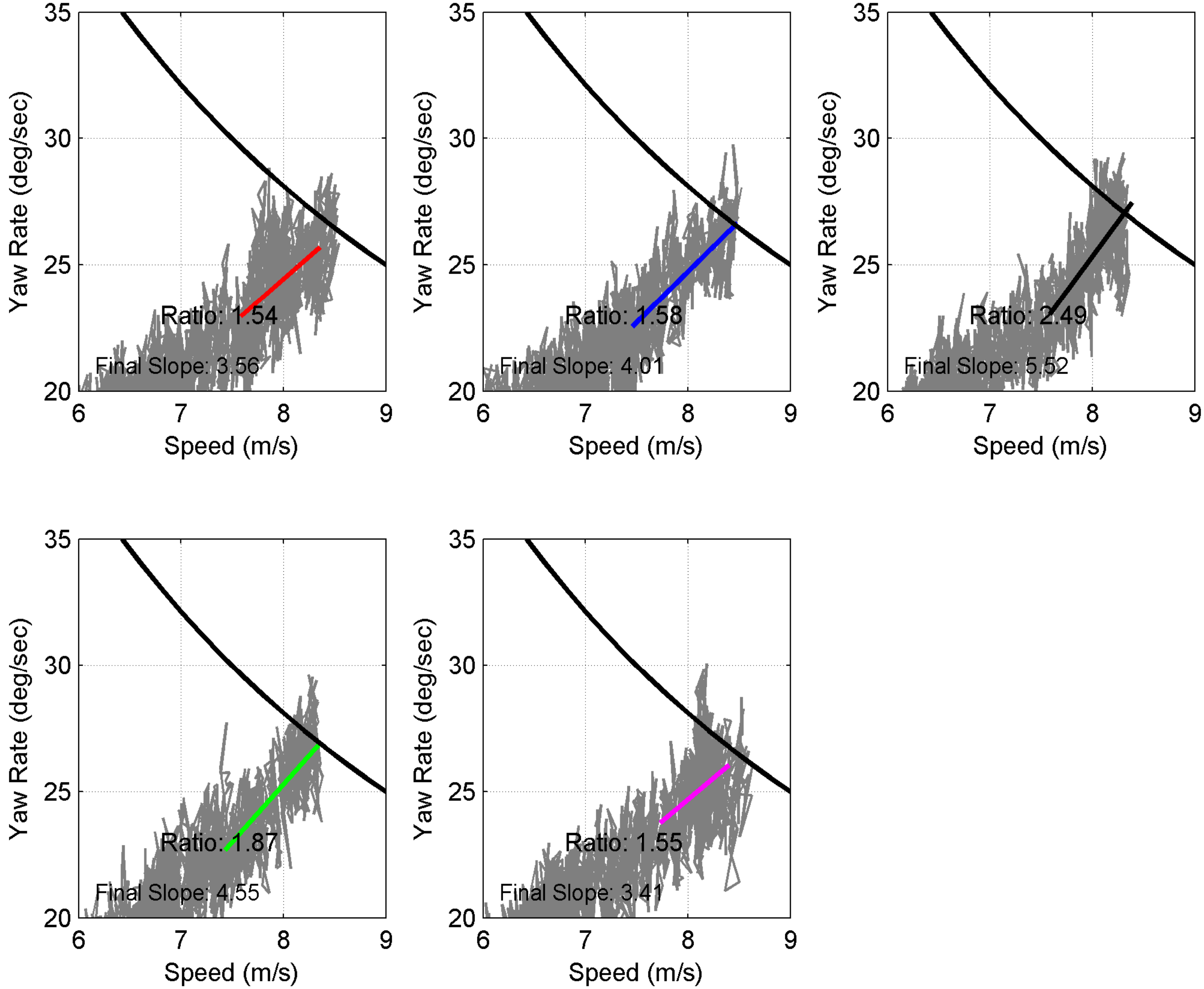

Vehicle L - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Roadwheel Steer Angle (deg)
10
5
0
-5
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)


Vehicle L
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

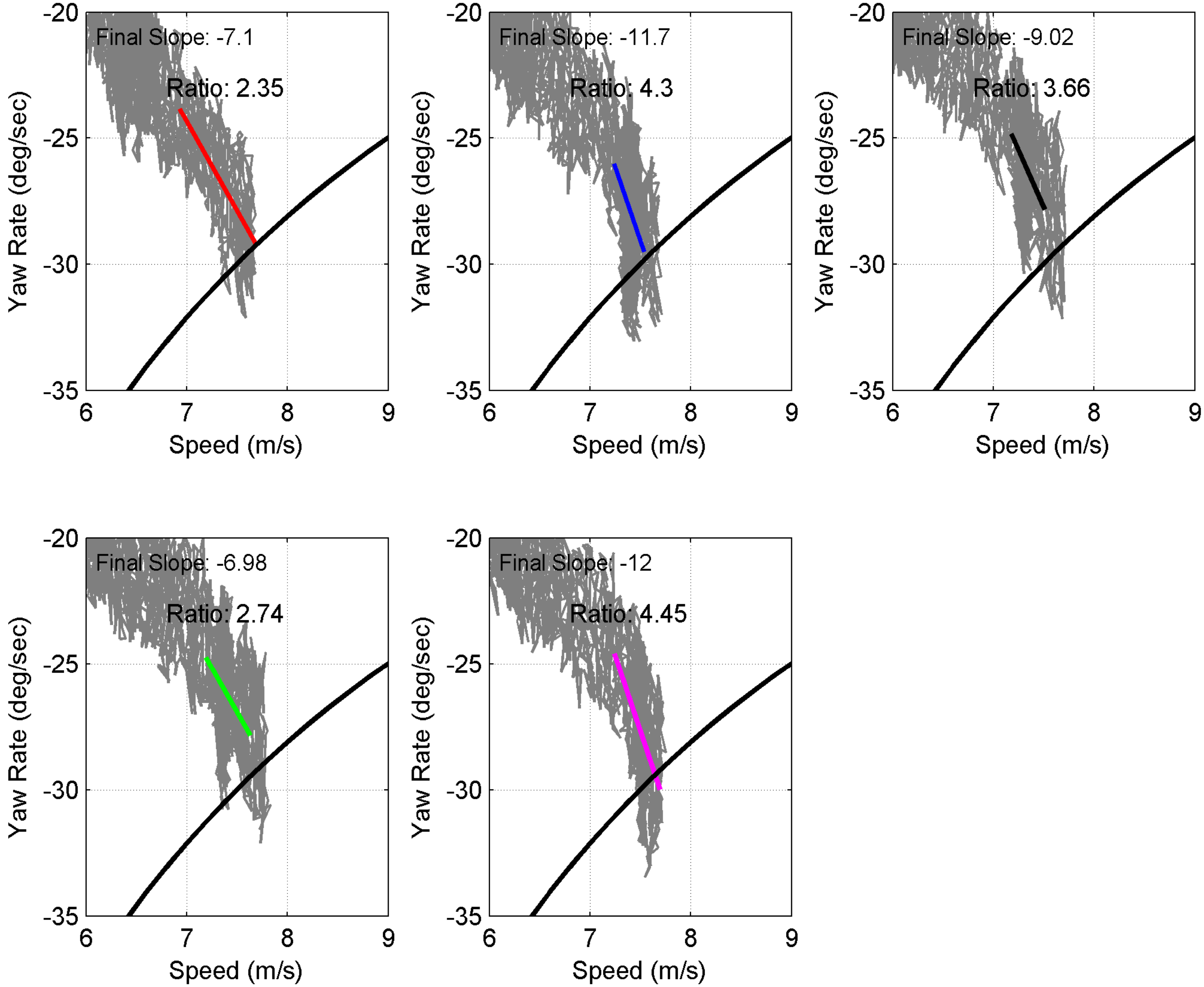

Vehicle L - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
Speed (m/s)


Vehicle L - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 2.31 2.54 2.21 2.43 2.2 STD=0.145
CW Final Slopes: 3.56 4.01 5.52 4.55 3.41 STD=0.858
CW Ratios: 1.54 1.58 2.49 1.87 1.55 STD=0.407
CW Average: 1.81
Average Ratio: 2.65
CCW Average: 3.5
CCW Ratios: 2.35 4.3 3.66 2.74 4.45 STD=0.93
CCW Final Slopes: -7.1 -11.7 -9.02 -6.98 -12 STD=2.4
CCW Initial Slopes: -3.02 -2.72 -2.47 -2.55 -2.69 STD=0.212
Yaw Rate (deg/sec)
Speed (m/s)
40
30
20
10
0
-10
-20
-30
-40
2
3
4
5
6
7
8
9

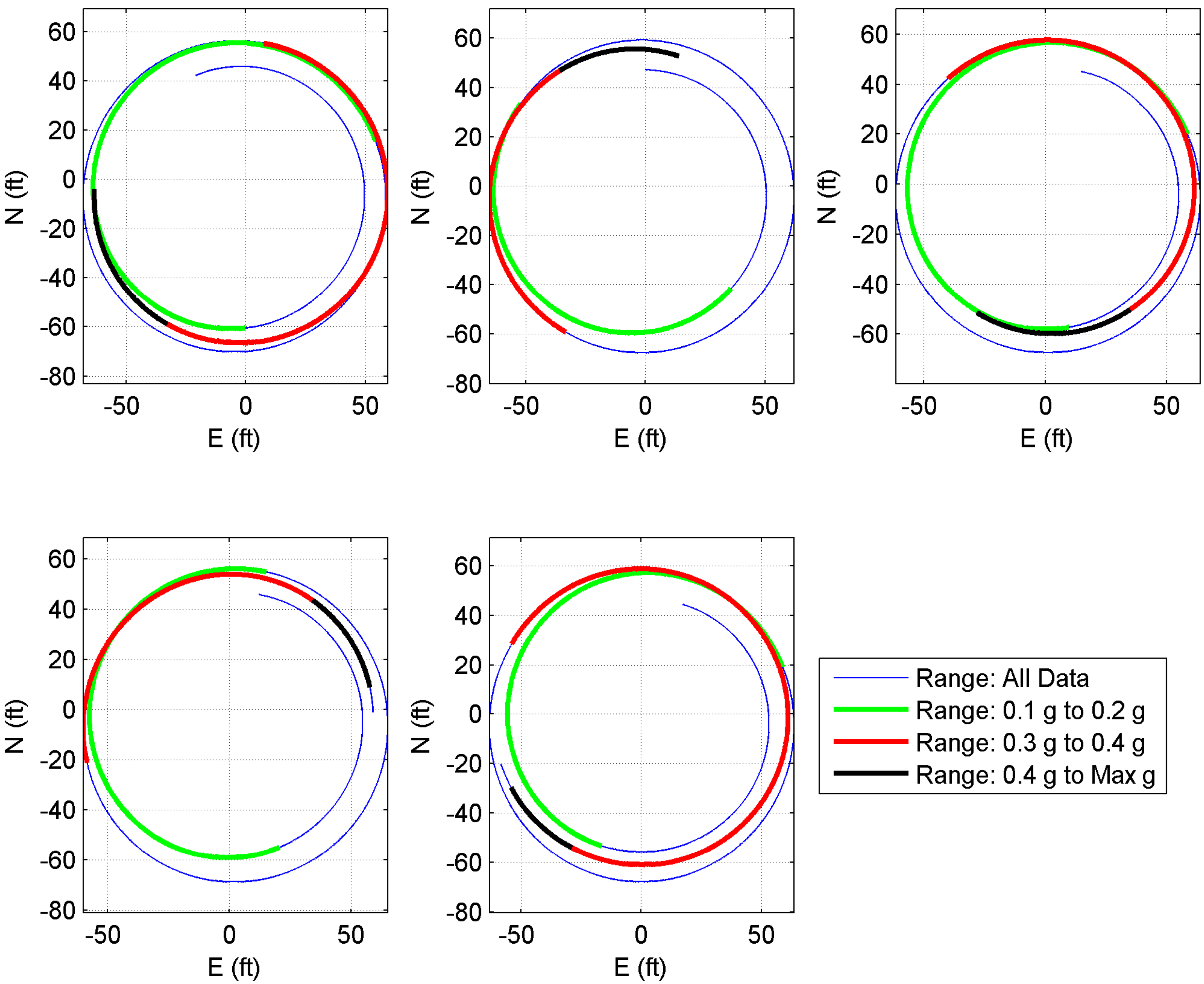
Vehicle L - 50 ft Radius - Constant Steer Test - CW Runs



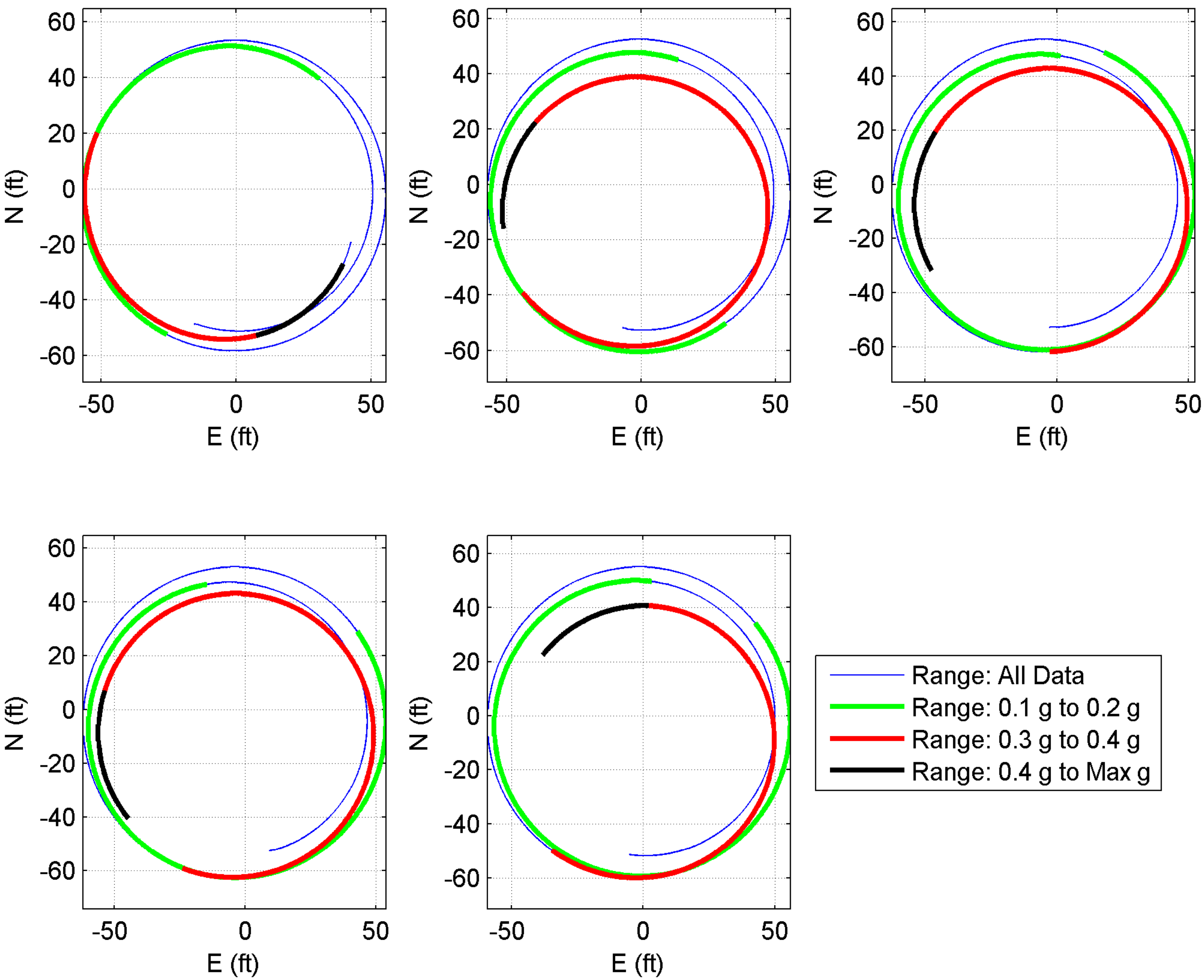
Vehicle L - 50 ft Radius - Constant Steer Test - CCW Runs

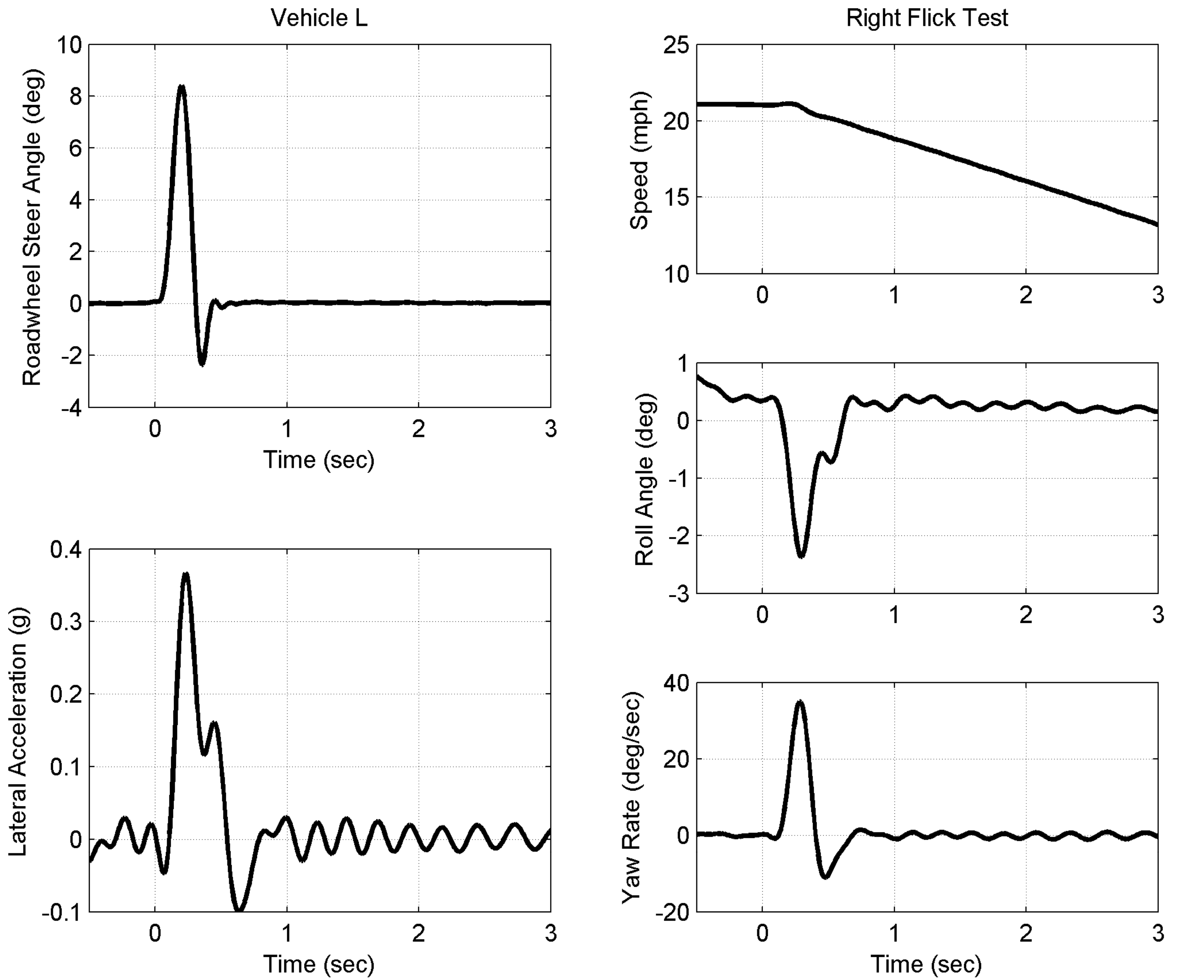


Vehicle L - 50 ft Radius - Constant Steer Test - CW Runs

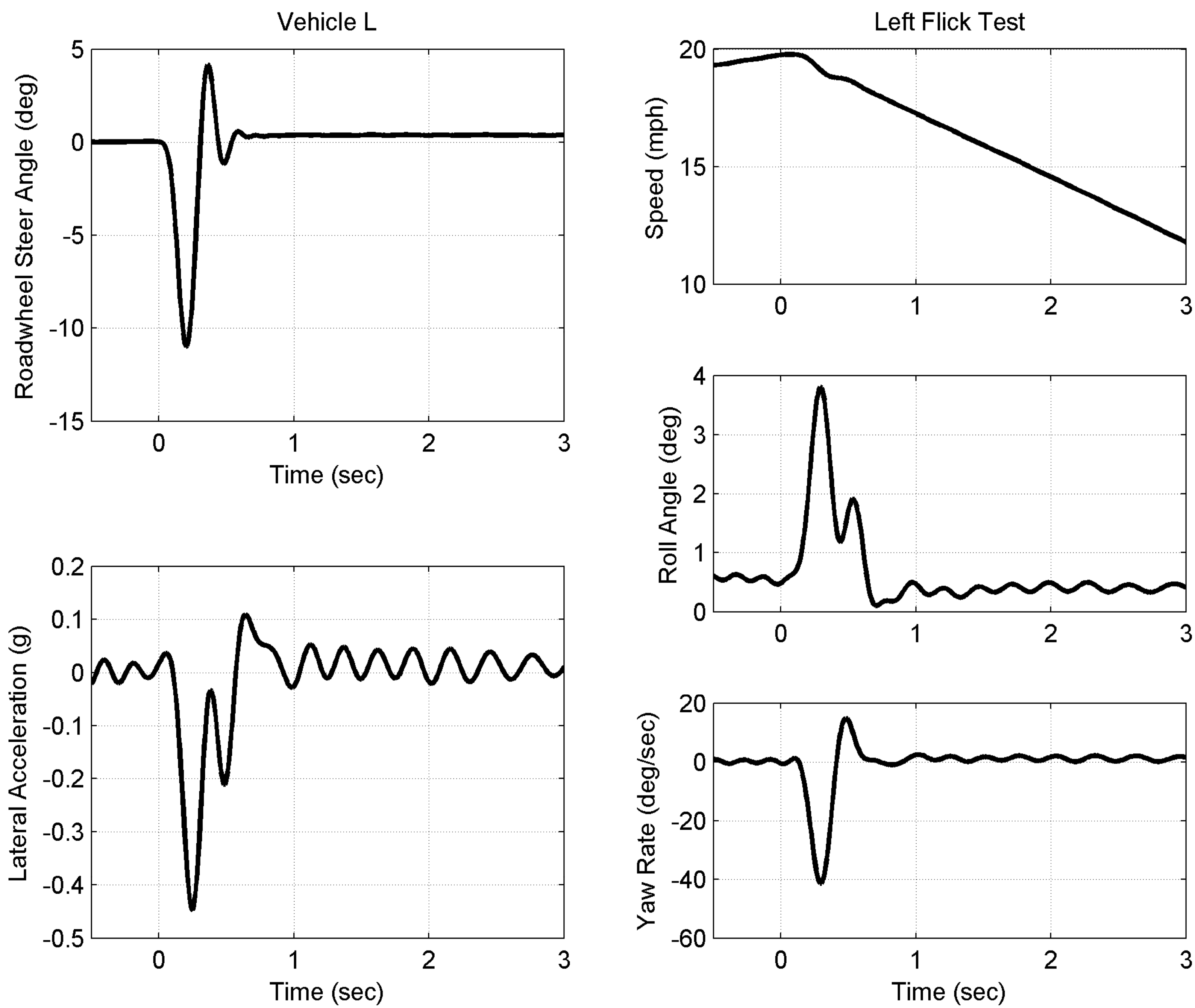


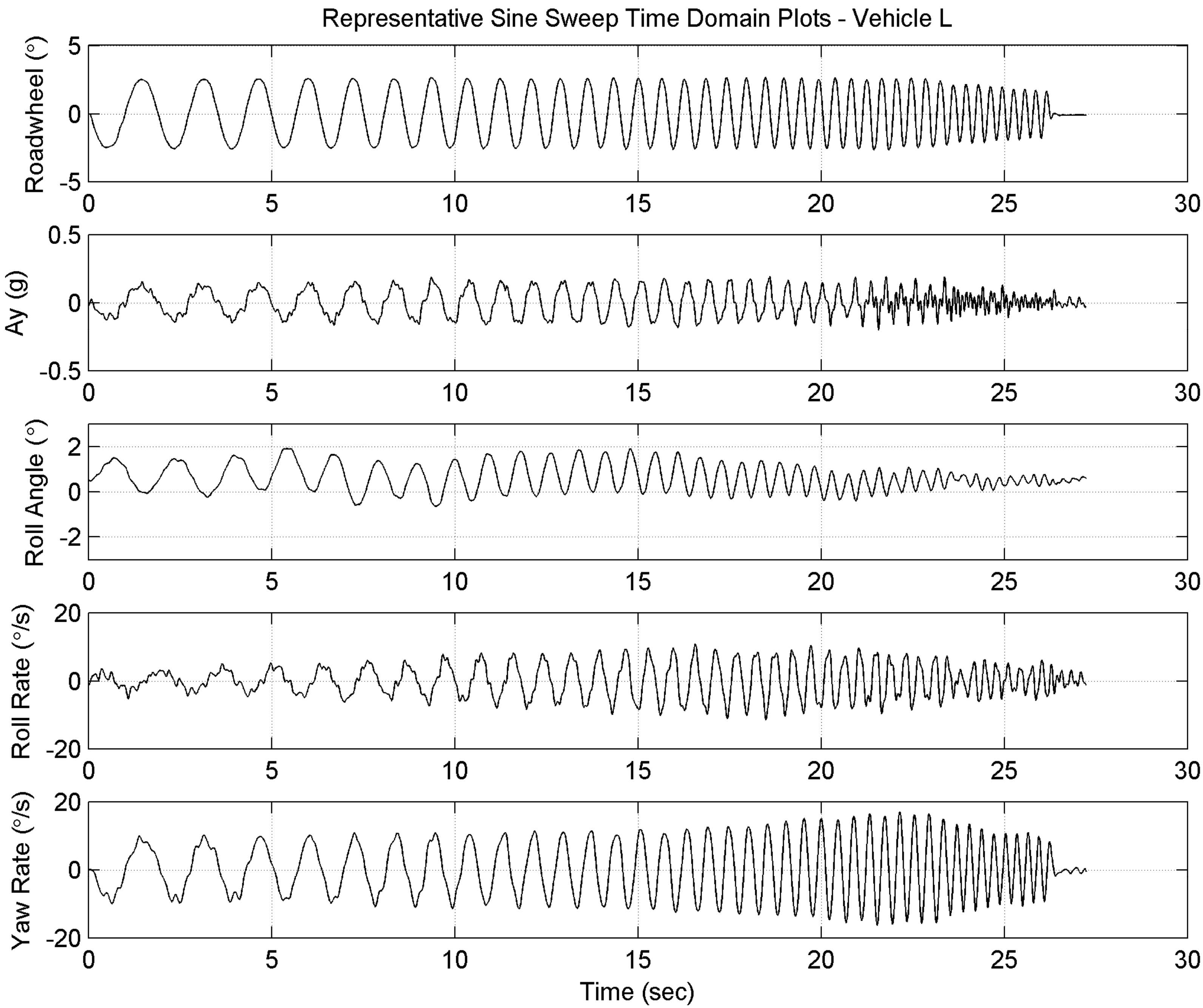
Vehicle L - 50 ft Radius - Constant Steer Test - CCW Runs

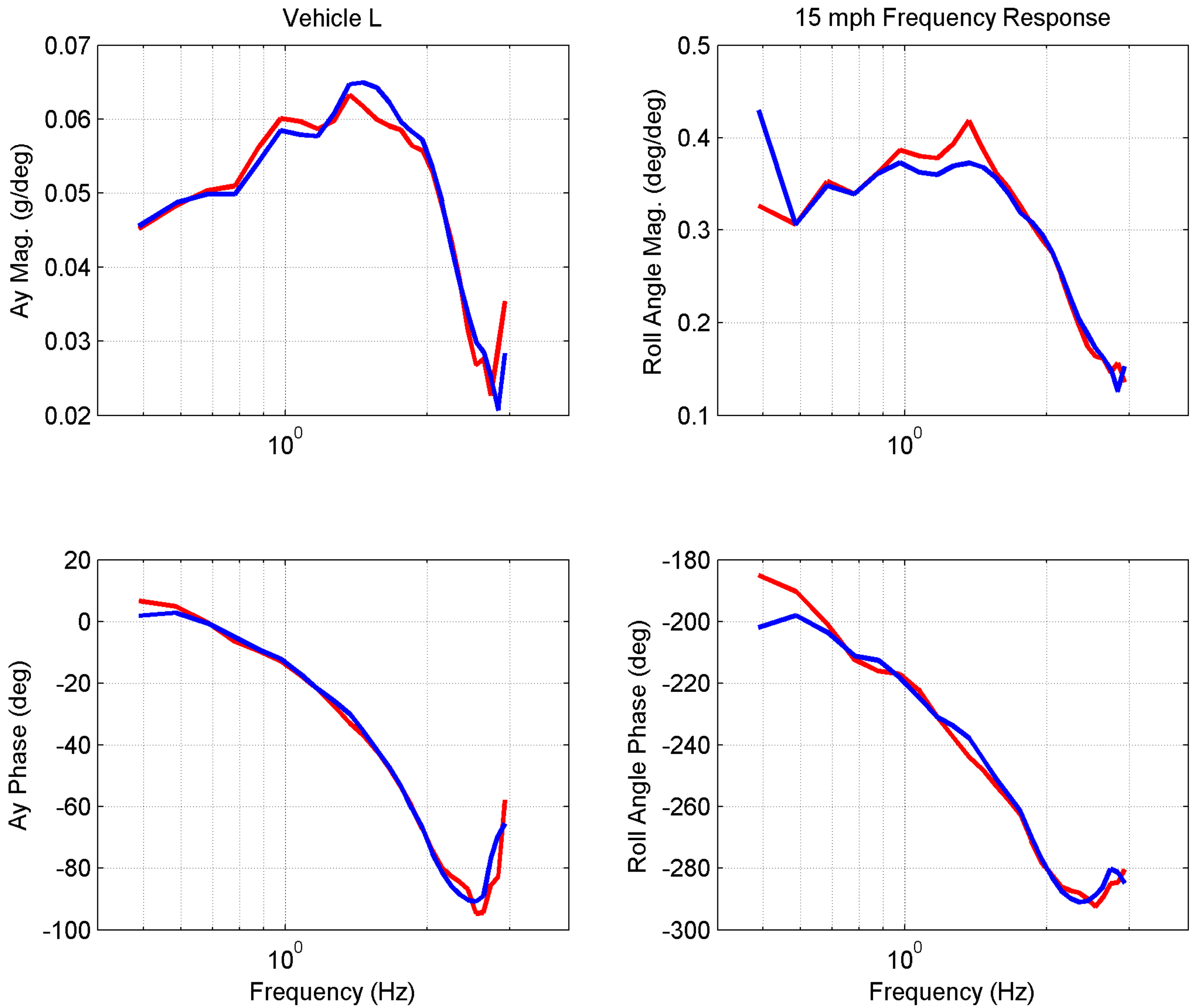




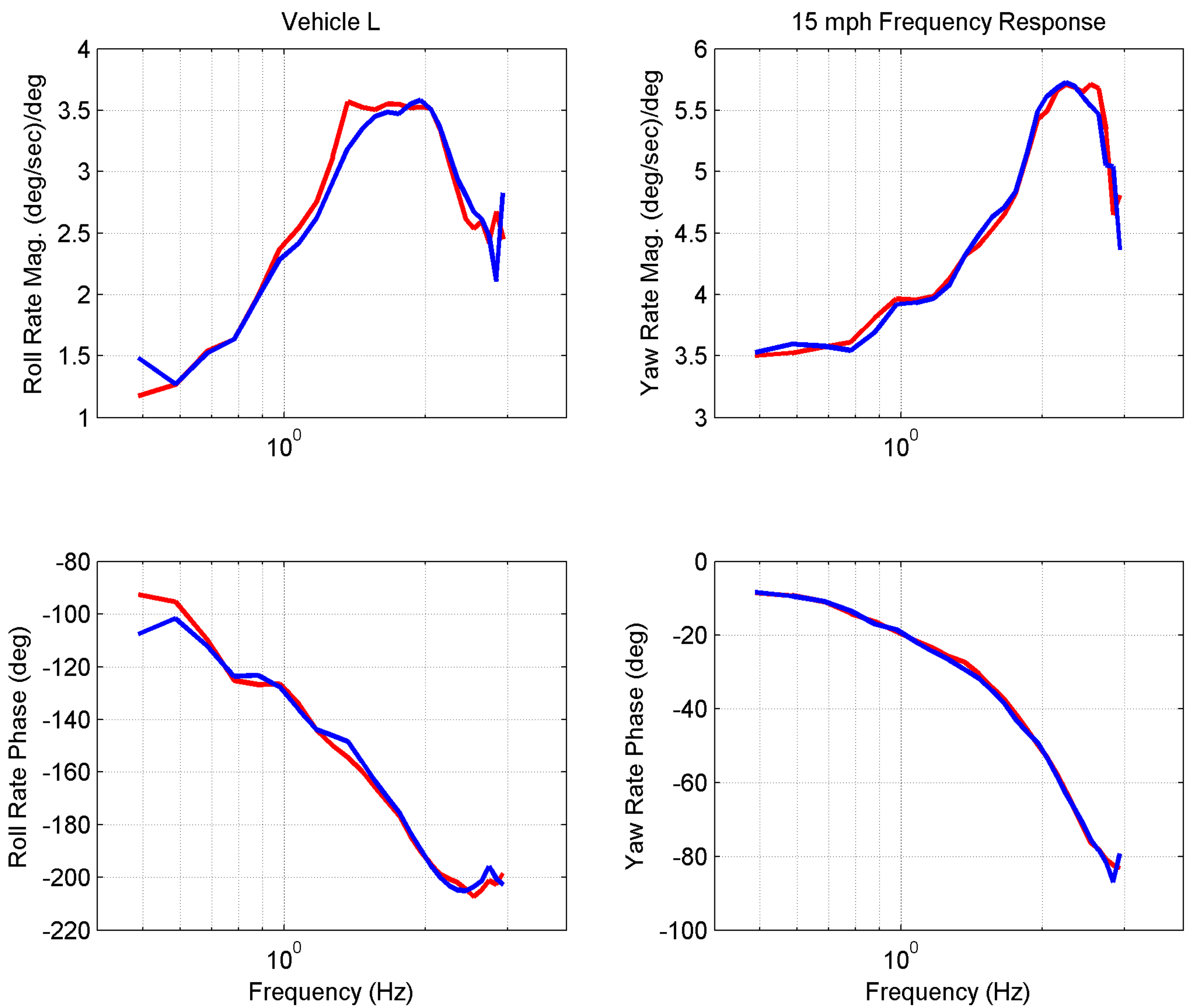
Vehicle L
Right Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

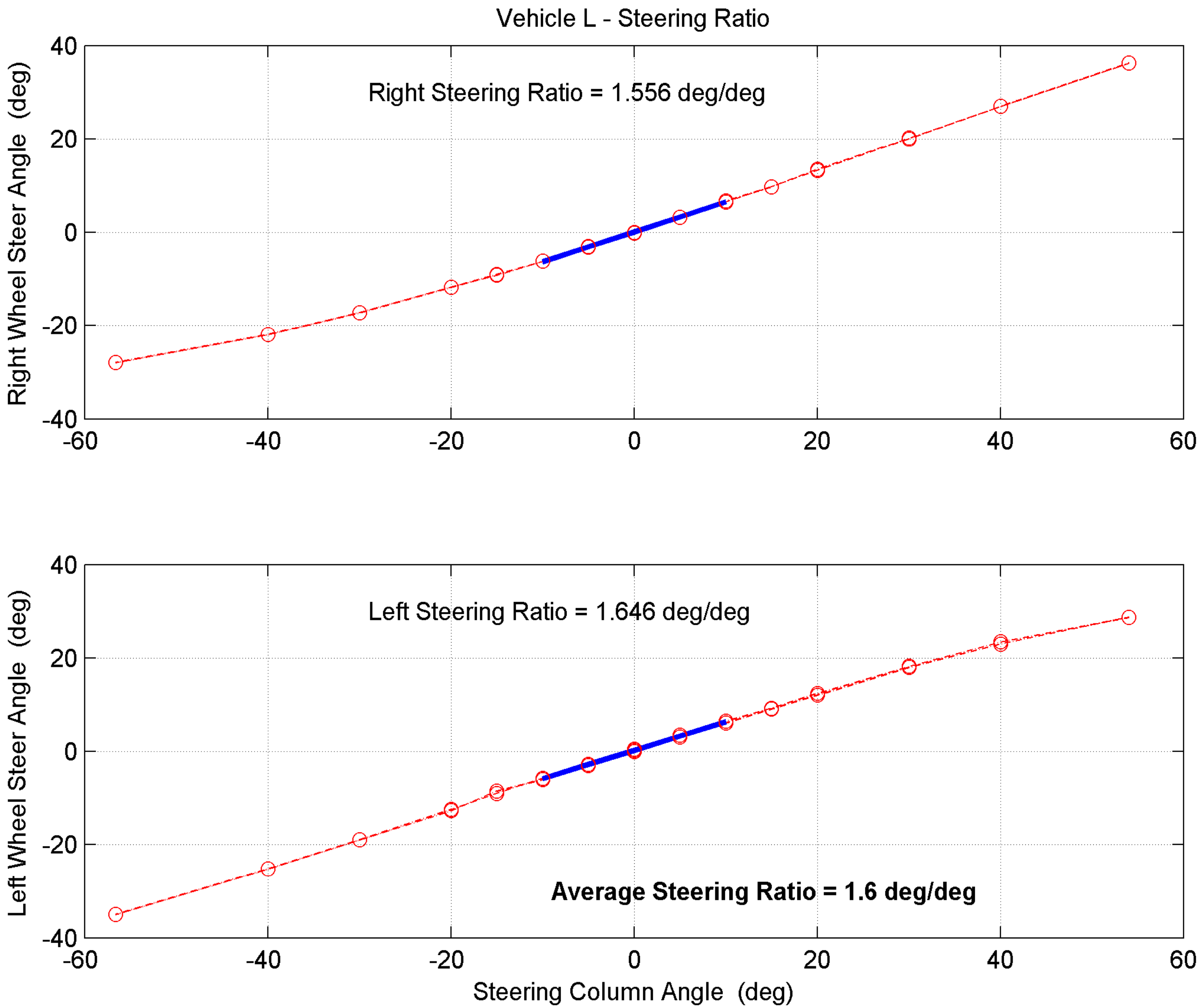

Vehicle L
Left Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

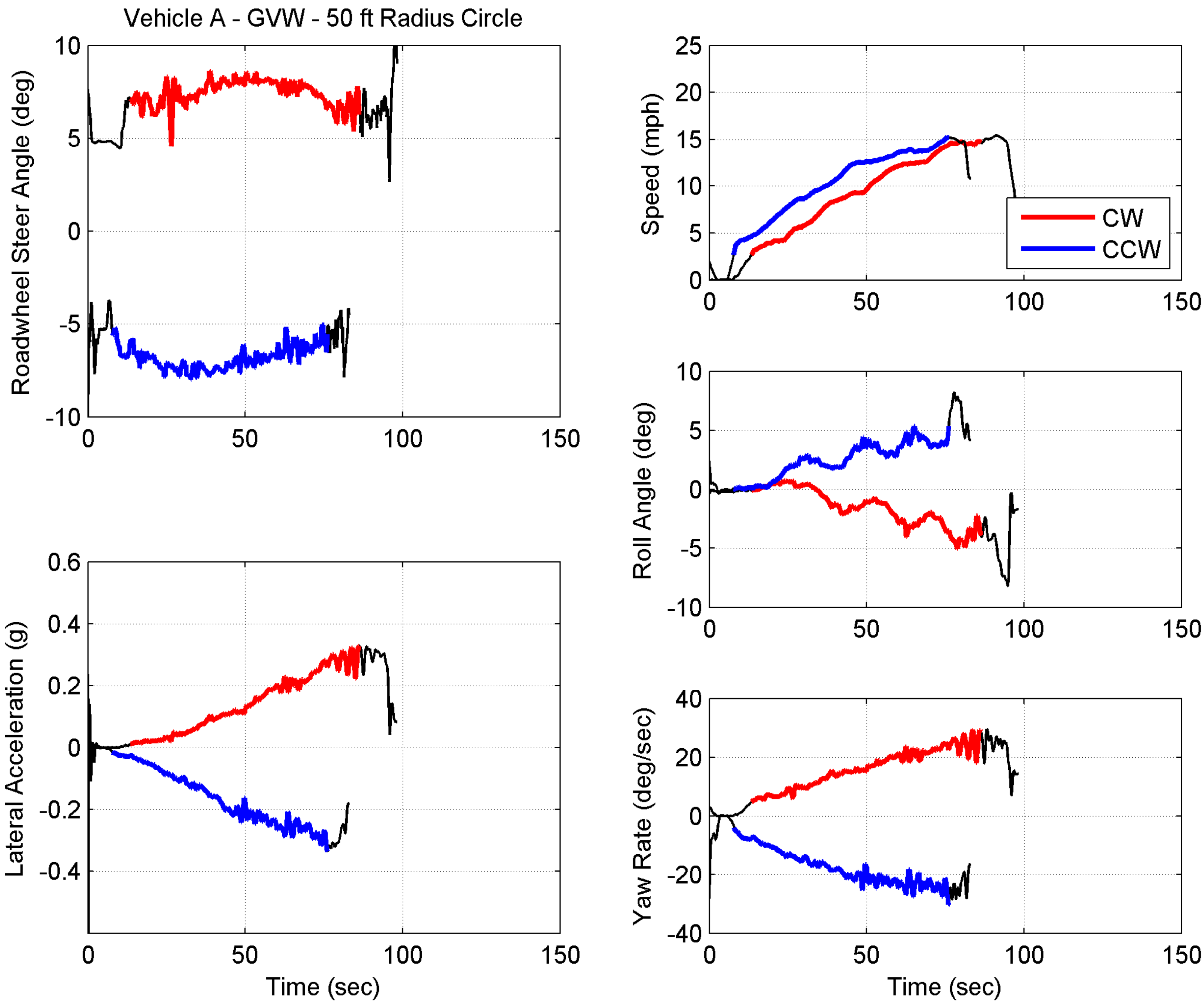

Representative Sine Sweep Time Domain Plots - Vehicle L
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

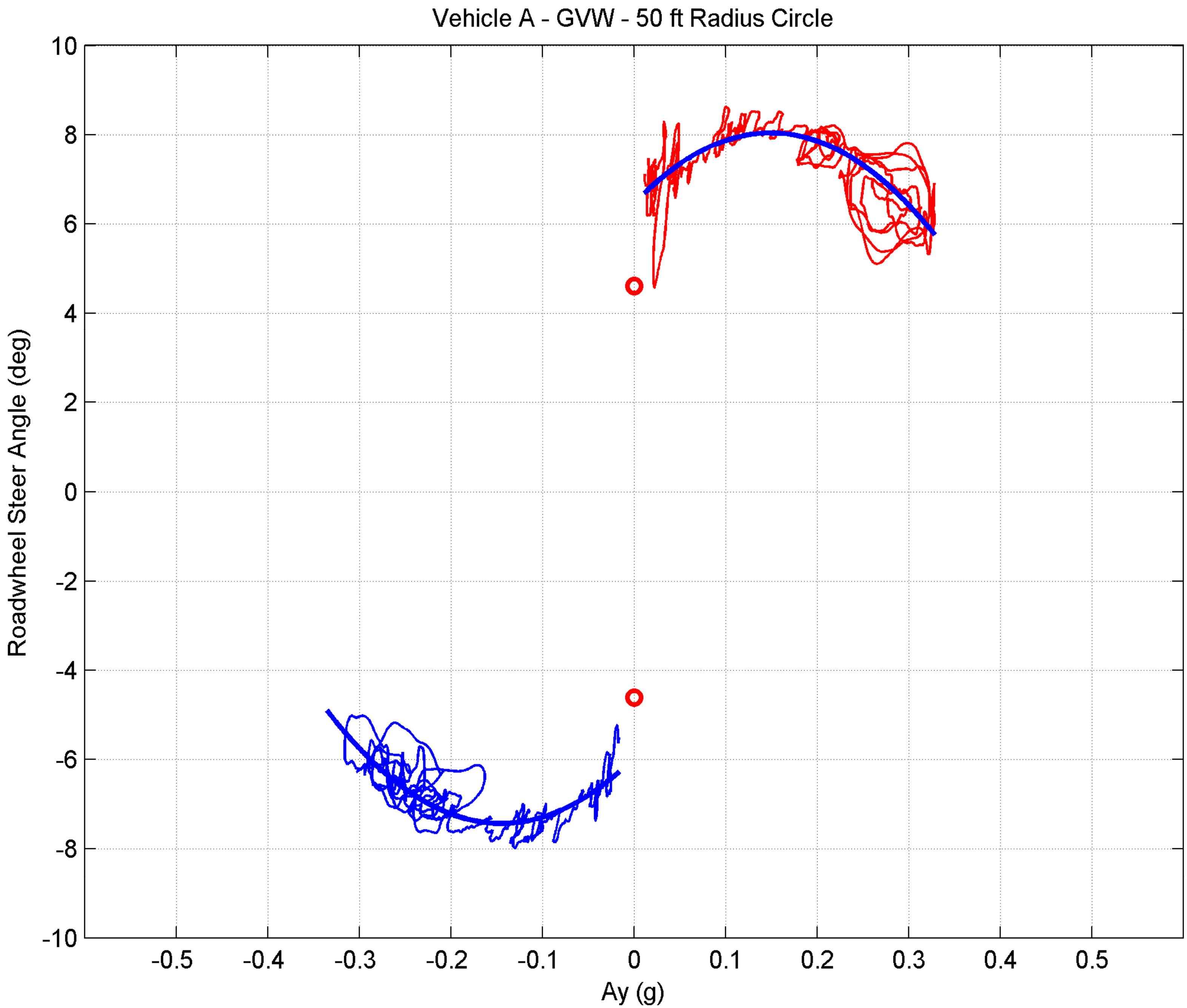


Vehicle L
15 mph Frequency Response
Ay Mag. (g/deg)
0.07
0.06
0.05
0.04
0.03
0.02
Roll Angle Mag. (deg/deg)
0.5
0.4
0.3
0.2
0.1
Ay Phase (deg)
20
0
-20
-40
-60
-80
-100
Roll Angle Phase (deg)
-180
-200
-220
-240
-260
-280
-300
10^0
Frequency (Hz)

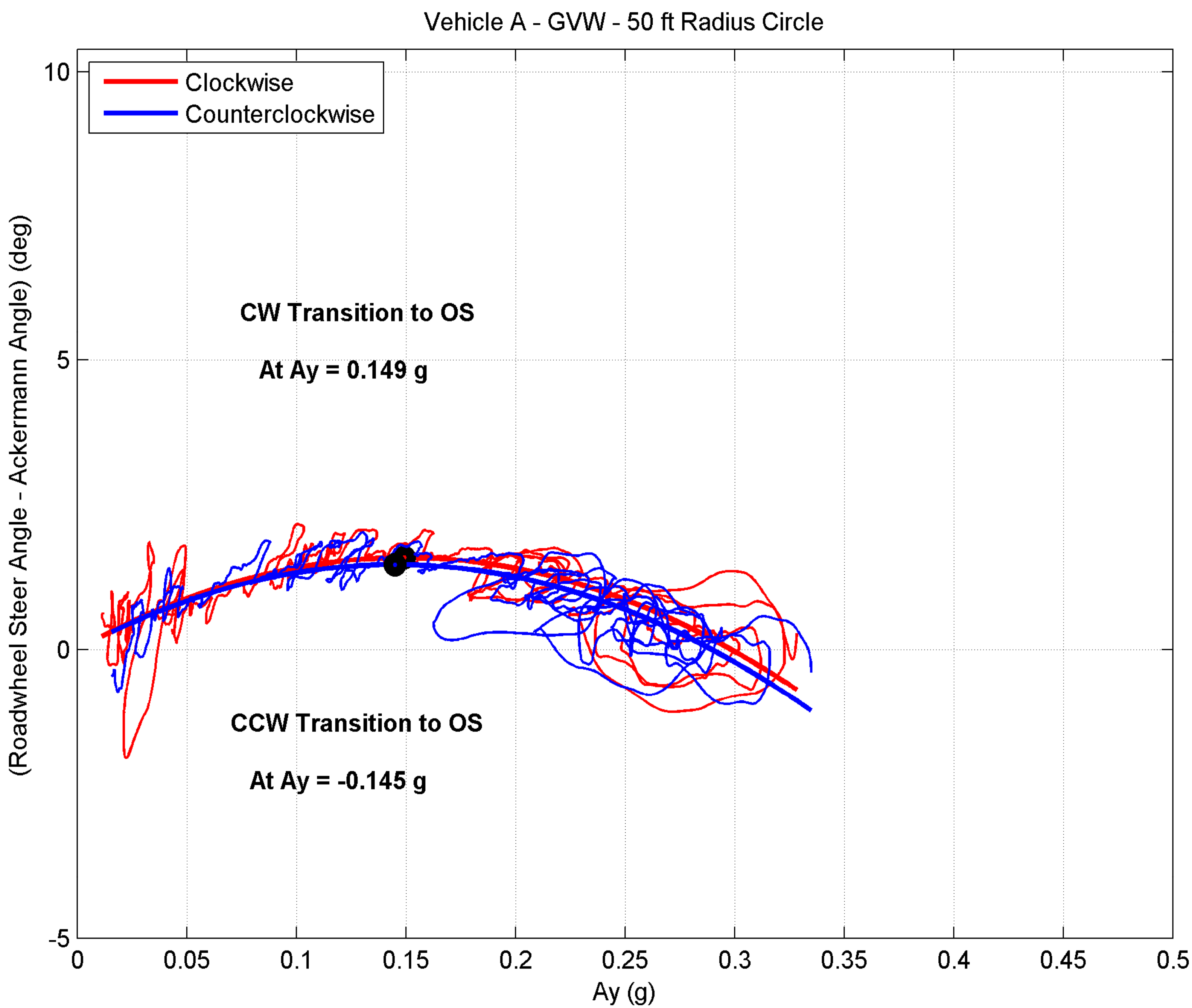

Vehicle L
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
4
3.5
3
2.5
2
1.5
1
6
5.5
5
4.5
4
3.5
3
-80
-100
-120
-140
-160
-180
-200
-220
0
-20
-40
-60
-80
-100
10^0


Vehicle L - Steering Ratio
Right Steering Ratio = 1.556 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-60
-40
-20
0
20
40
60
Left Steering Ratio = 1.646 deg/deg
Average Steering Ratio = 1.6 deg/deg
Left Wheel Steer Angle (deg)
Steering Column Angle (deg)

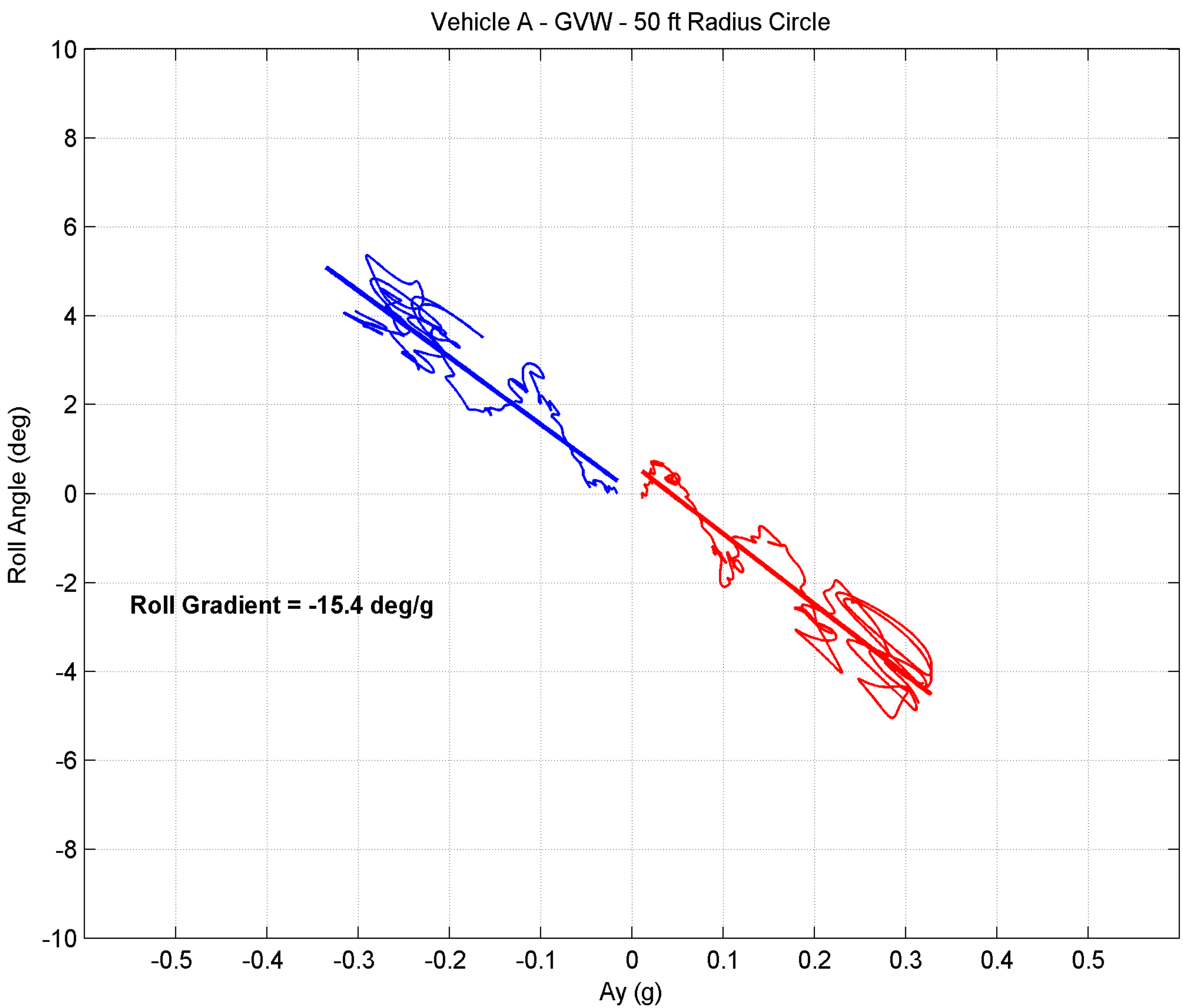

Vehicle A - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
CW
CCW
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

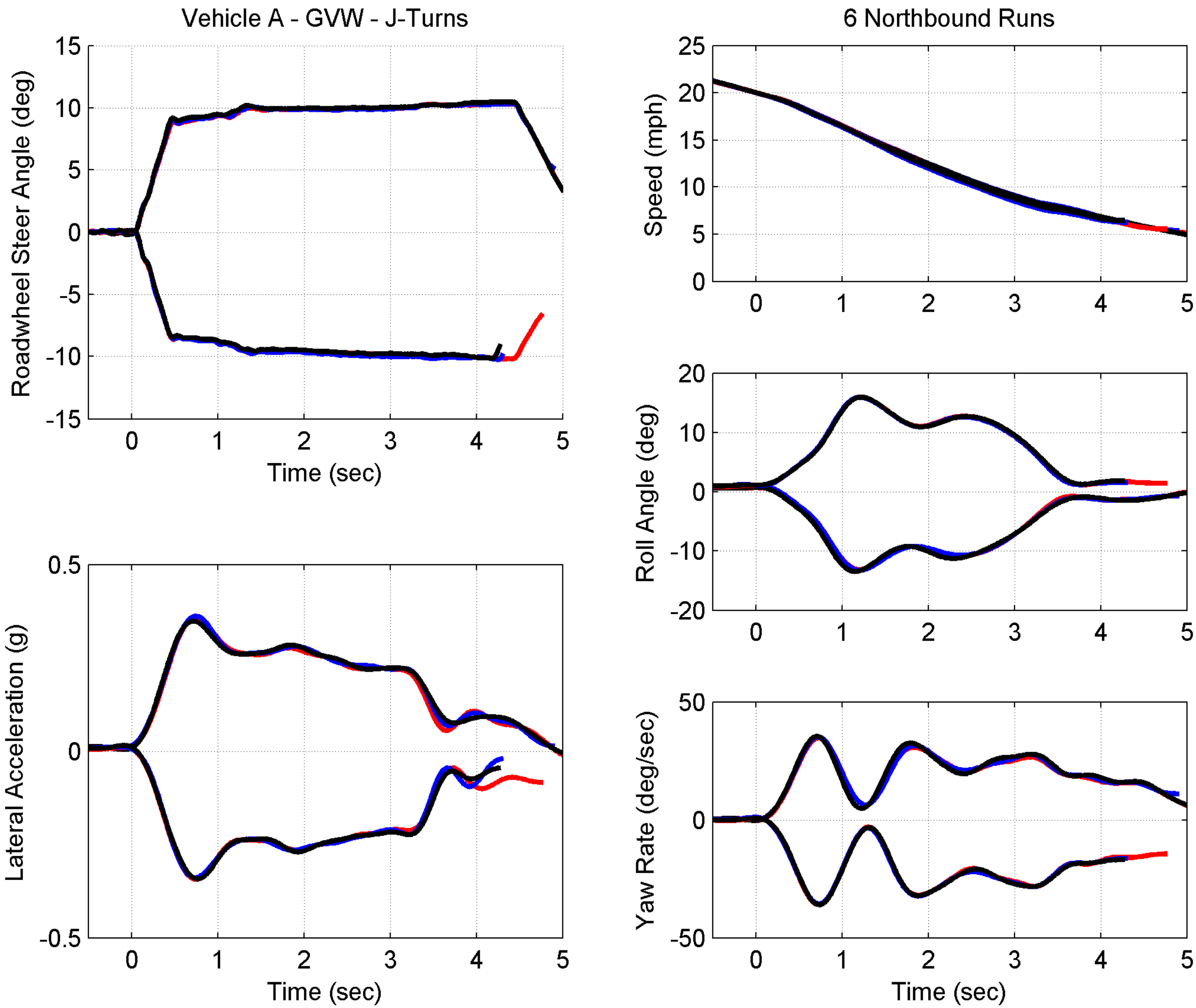


Vehicle A - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

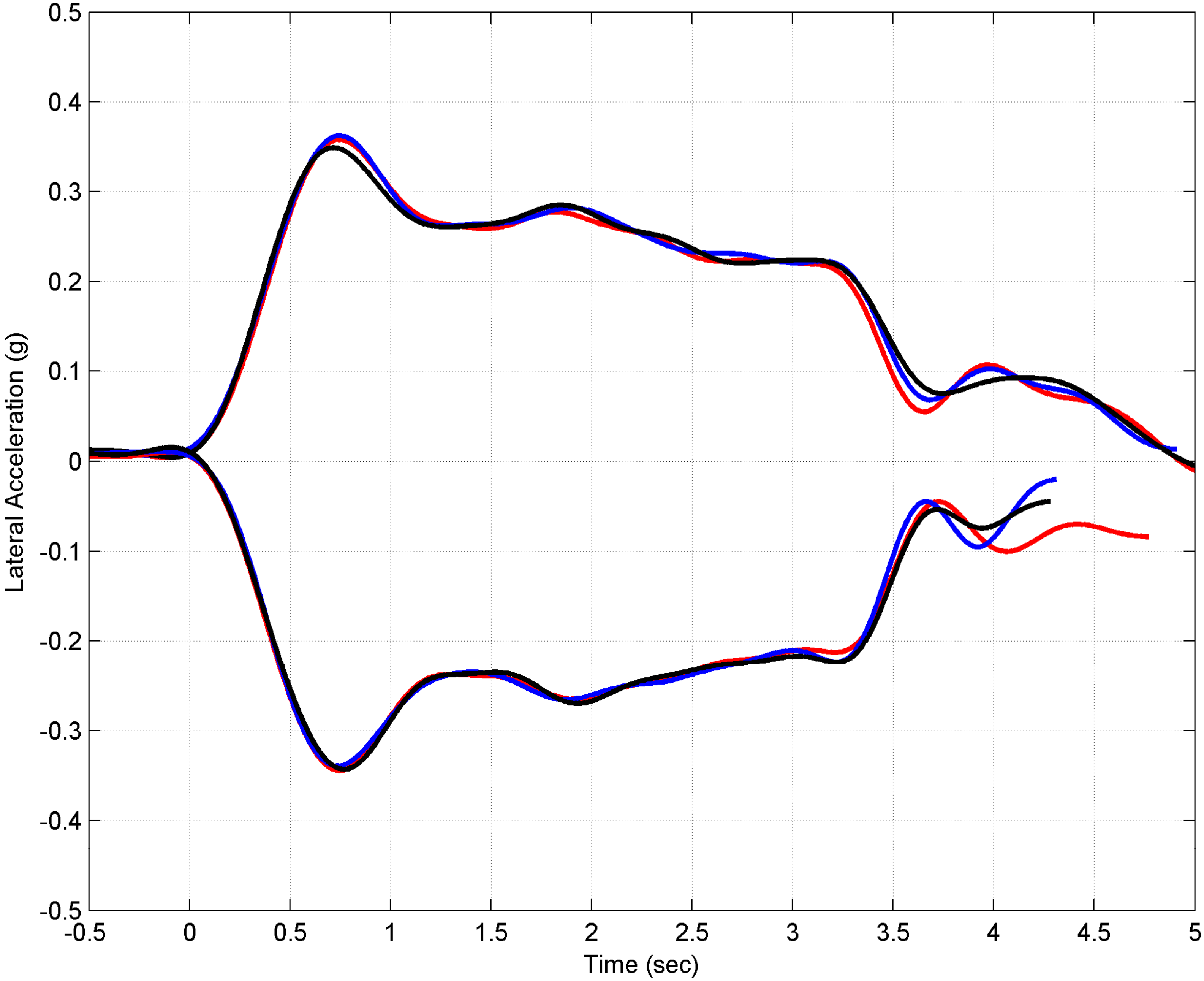


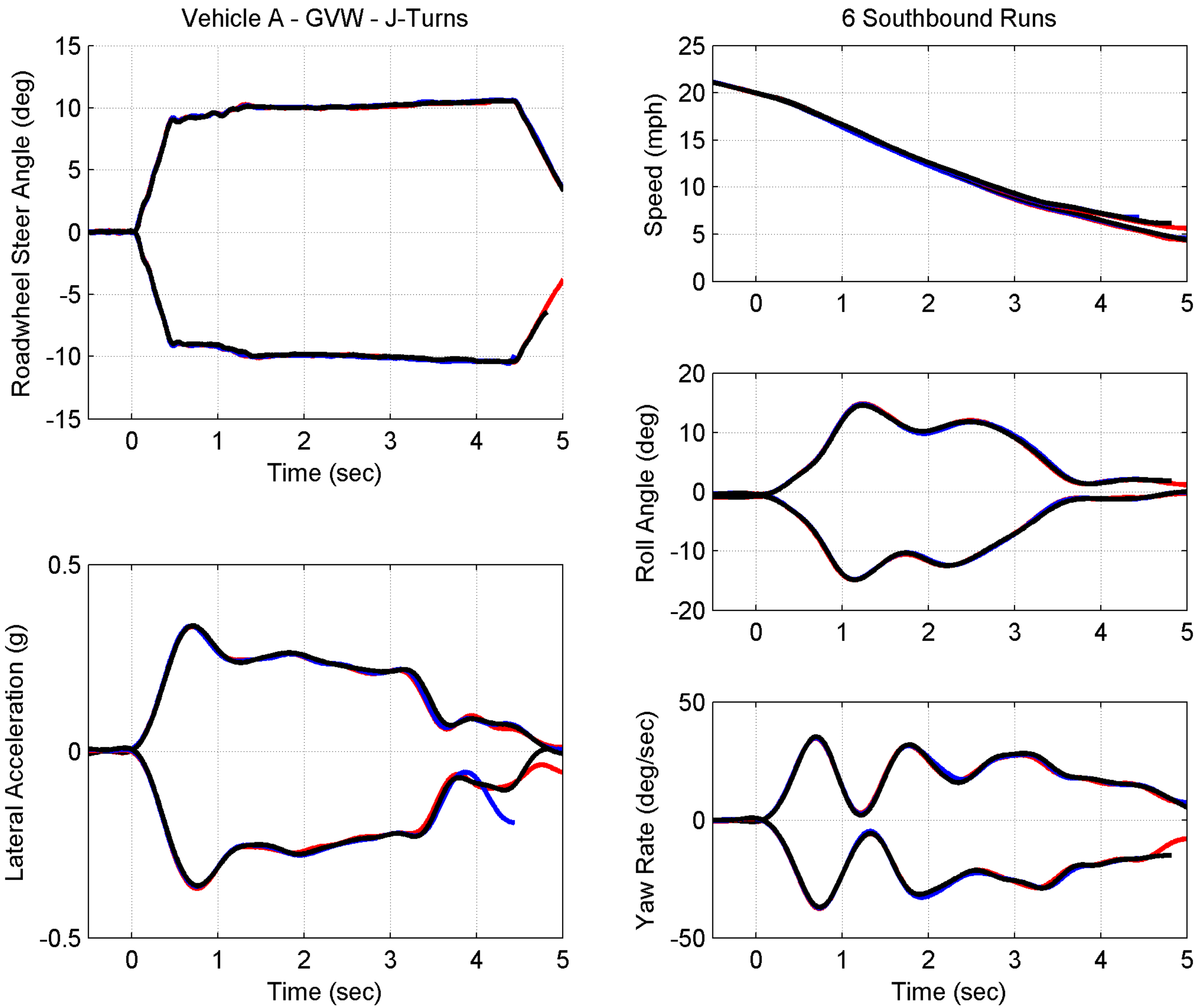
Vehicle A - GVW - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.149 g
CCW Transition to OS
At Ay = -0.145 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5


Vehicle A - GVW - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -15.4 deg/g
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

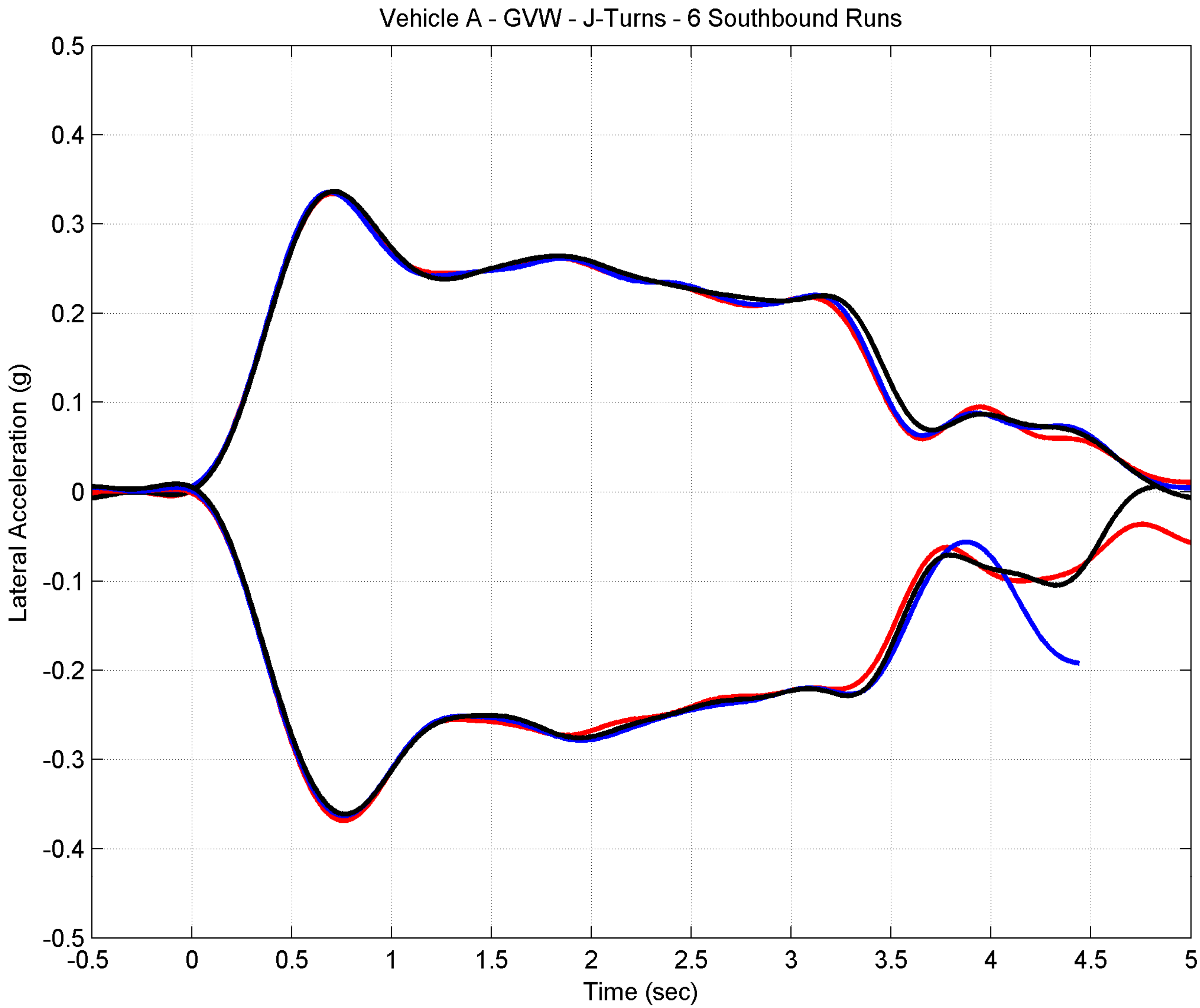

Vehicle A - GVW - J-Turns
6 Northbound Runs
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)
Speed (mph)
25
20
15
10
5
0
Roll Angle (deg)
20
10
0
-10
-20
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
50
0
-50

Vehicle A - GVW - J-Turns - 6 Northbound Runs





Vehicle A - GVW - J-Turns
6 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



Vehicle A - GVW - J-Turns - 6 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle A - GVW

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.3579	-0.3444
2	0.3621	-0.3391
3	0.3488	-0.3430
Mean Value of 3 Runs	0.3562	-0.3421
Standard Deviation of 3 Runs	0.007	0.003

Average of 6 Northbound Runs

0.3492

Average of All 12 Runs

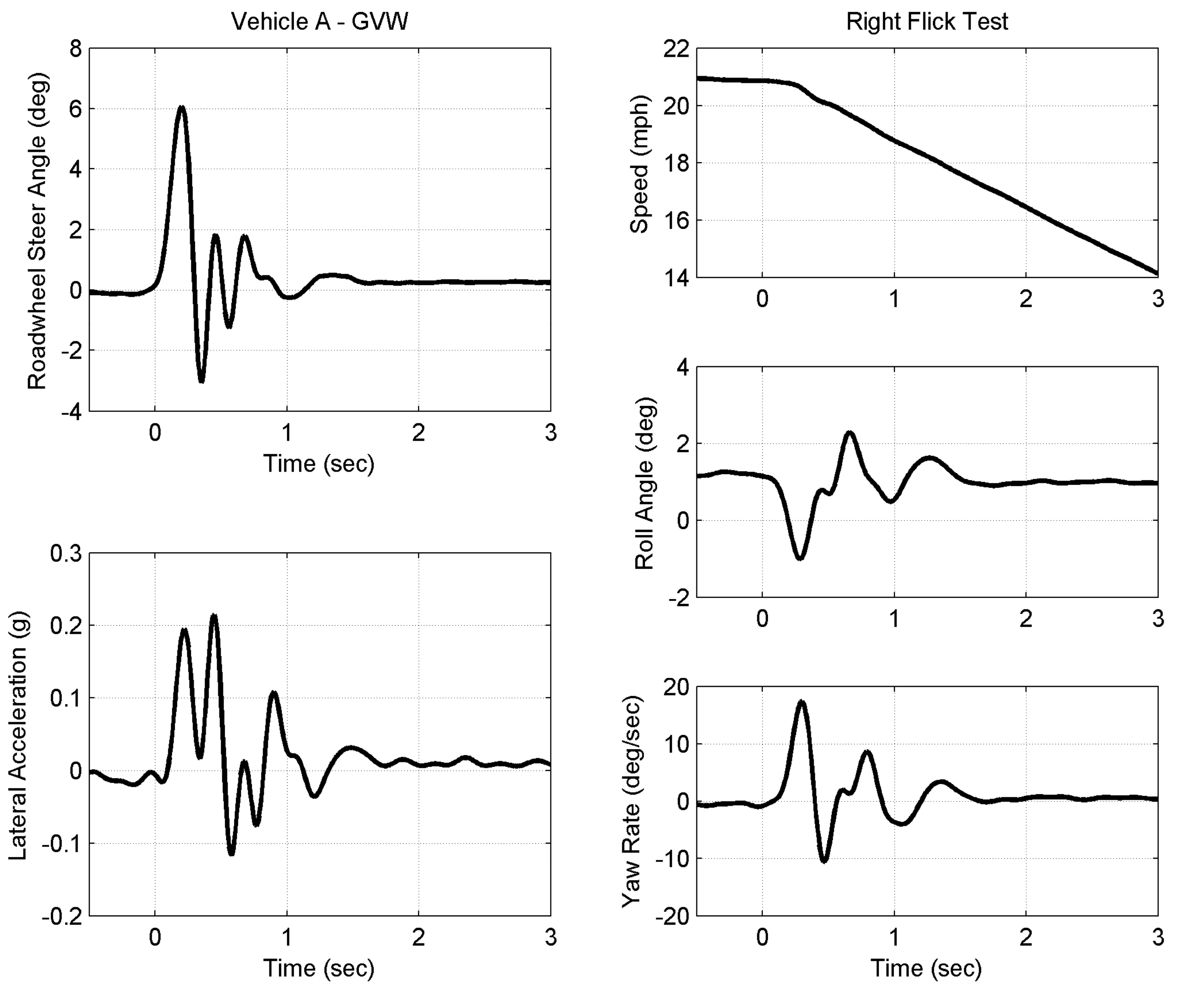
0.350

Threshold Ay

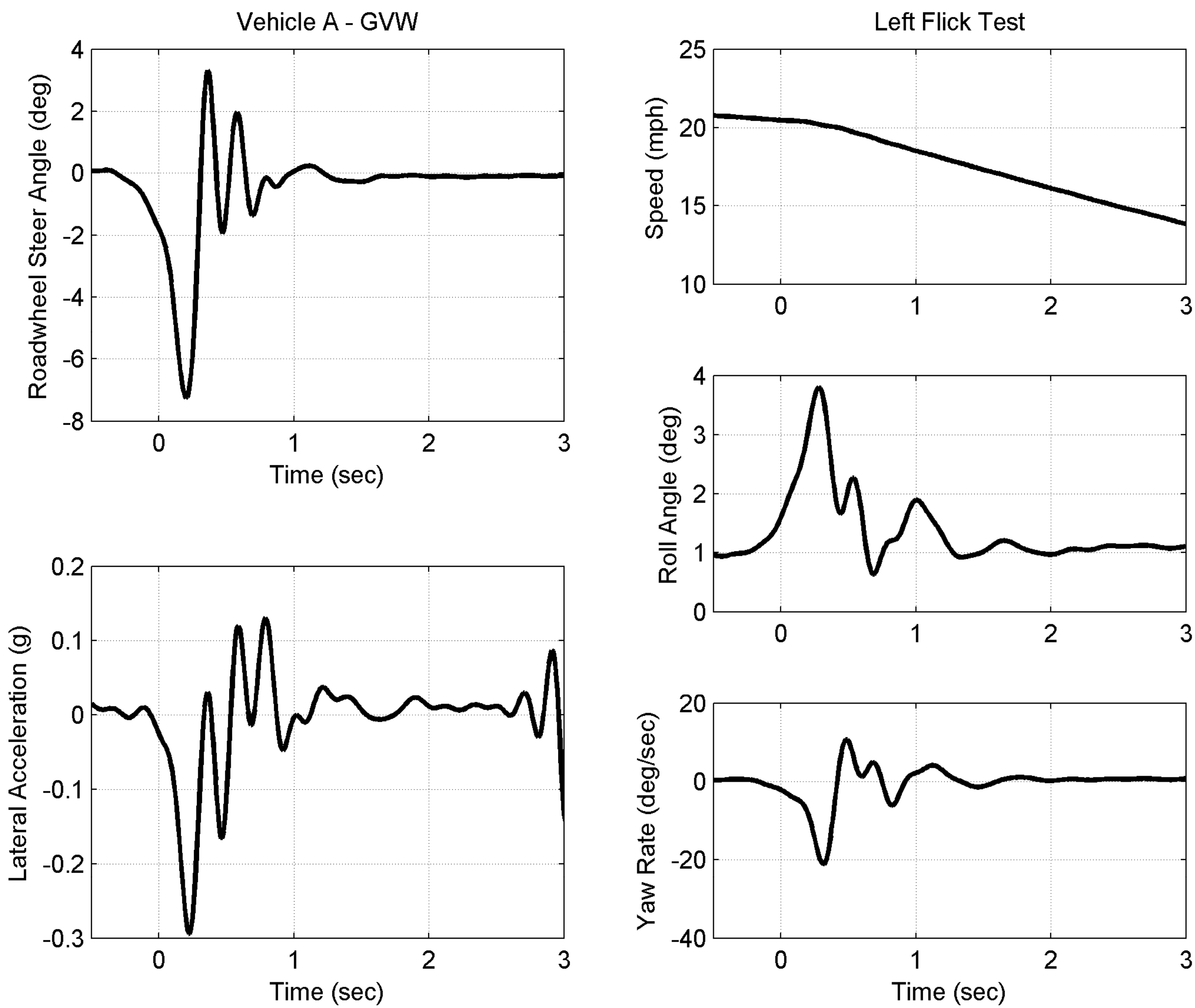
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.3339	-0.3688
2	0.3356	-0.3632
3	0.3363	-0.3612
Mean Value of 3 Runs	0.3353	-0.3644
Standard Deviation of 3 Runs	0.001	0.004

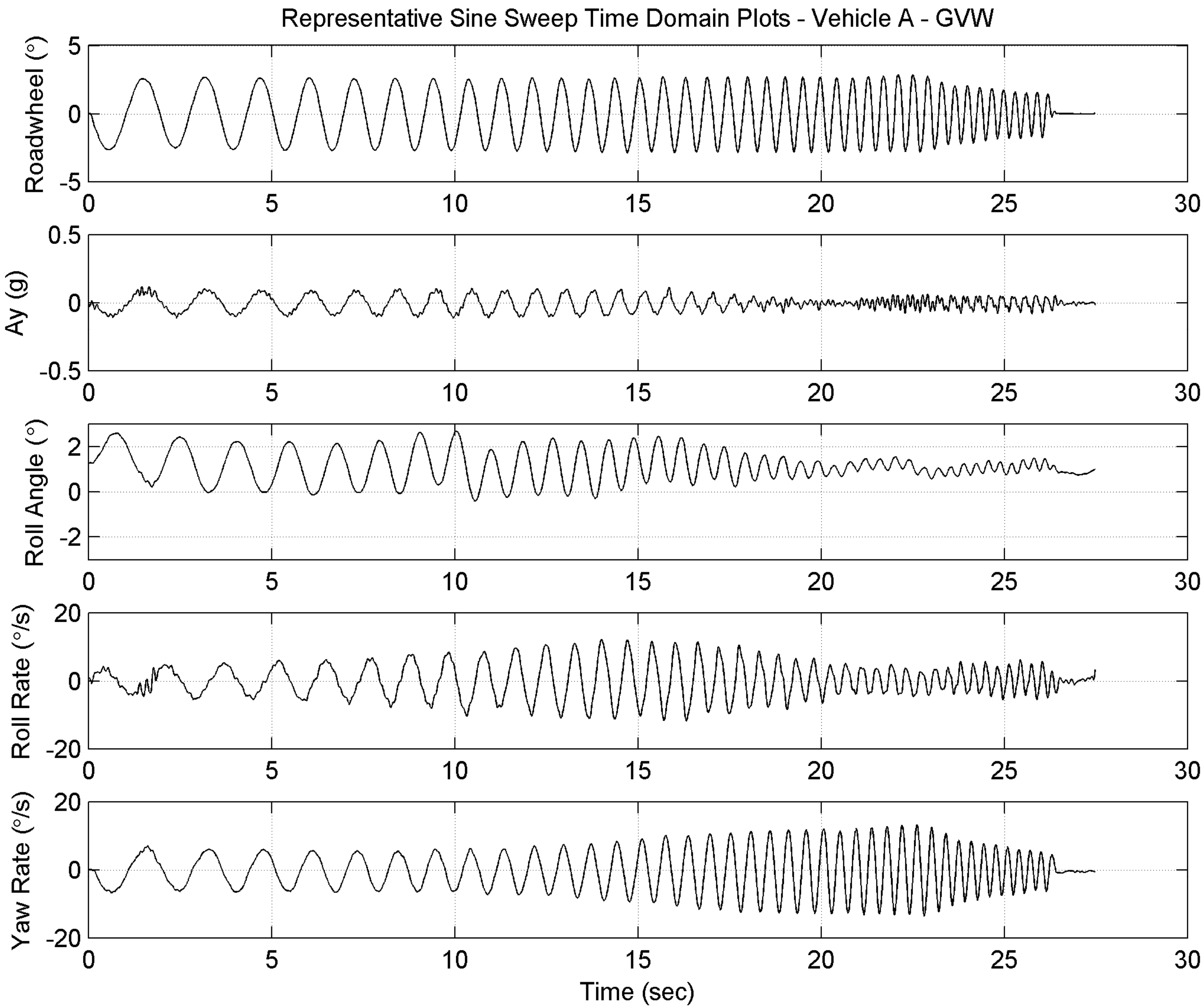
Average of 6 Southbound Runs

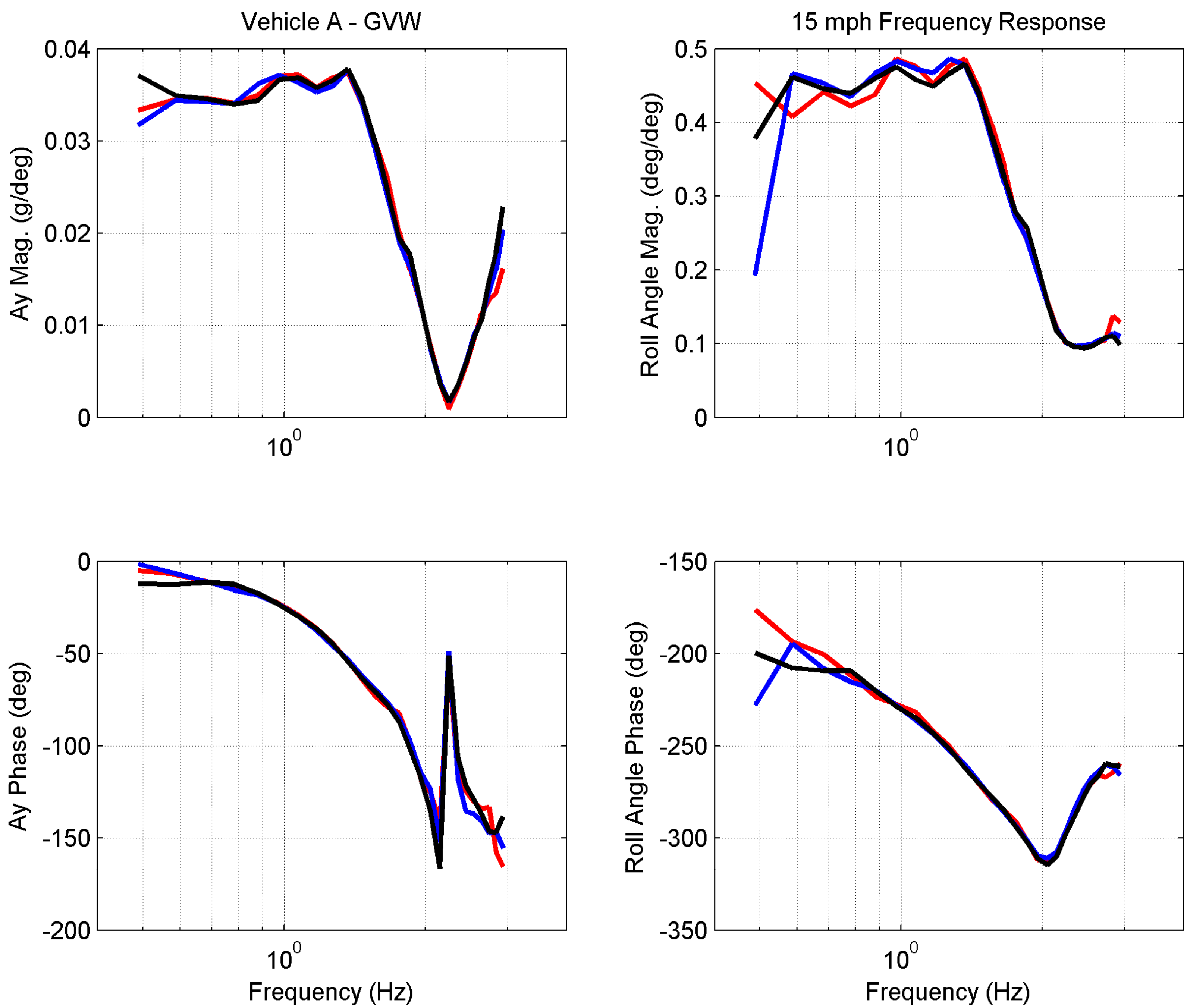
0.3498



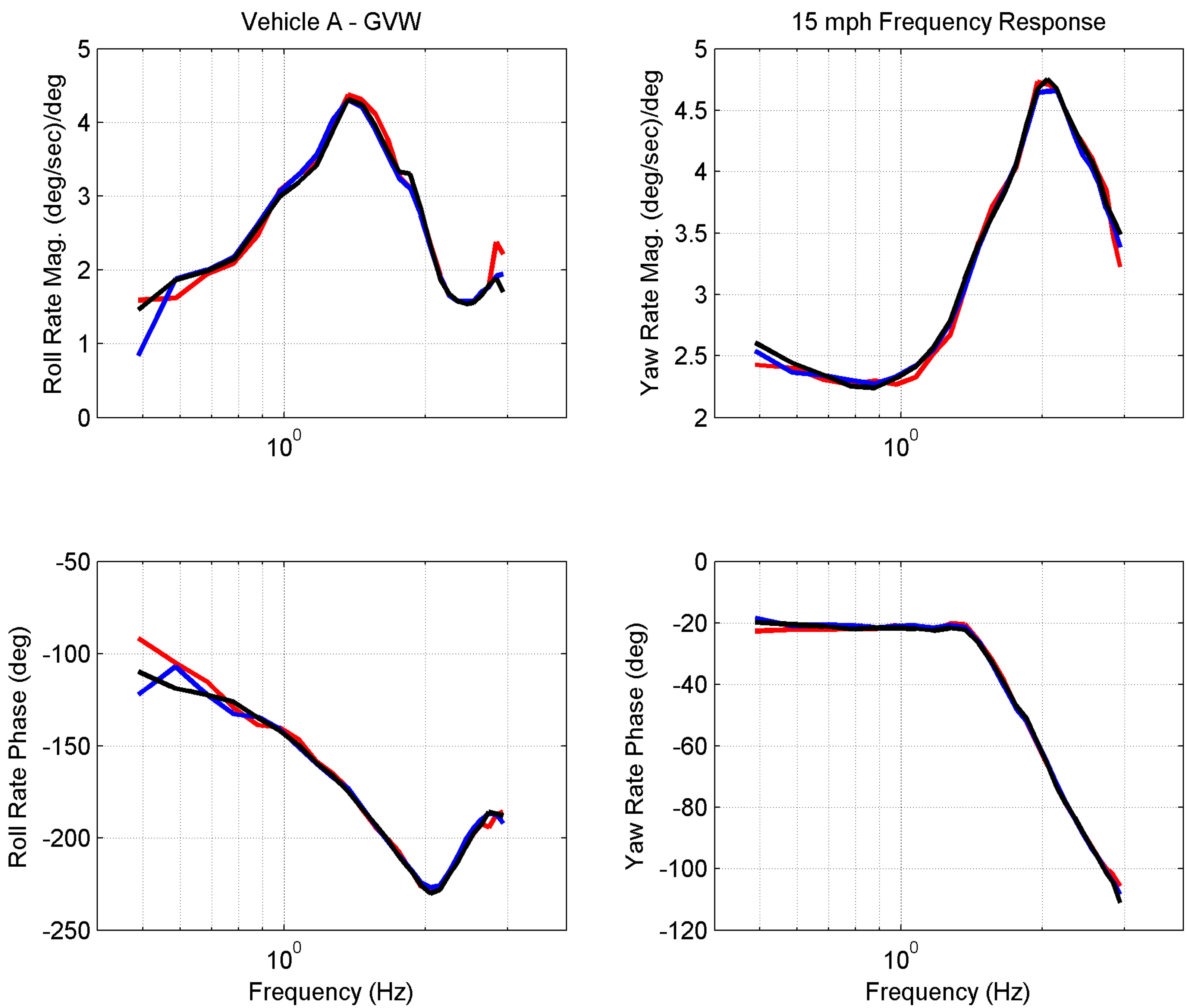
Vehicle A - GVW
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle A - GVW
Left Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

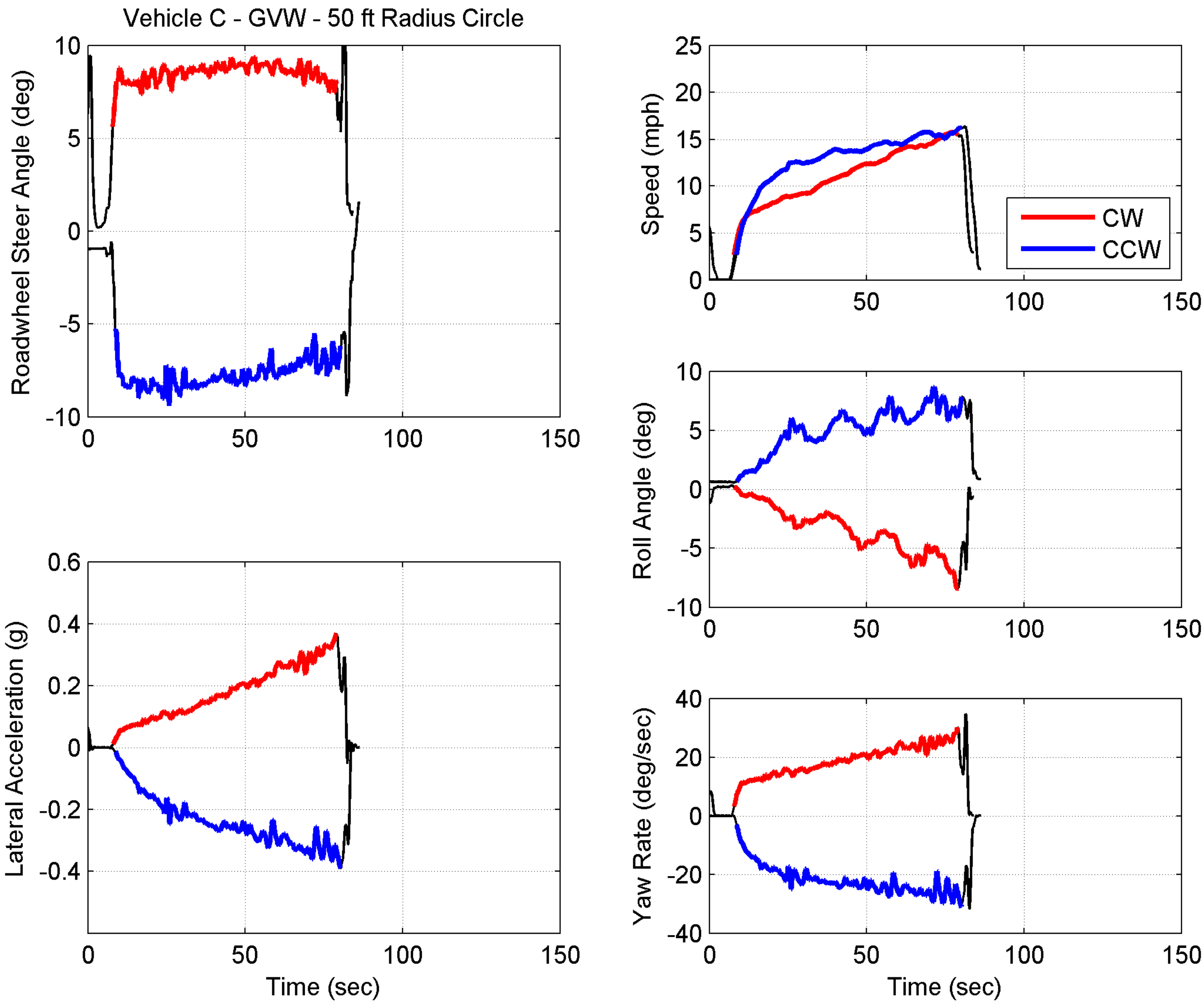

Representative Sine Sweep Time Domain Plots - Vehicle A - GVW
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)
5
0
-5
0.5
0
-0.5
2
0
-2
20
0
-20
20
0
-20
0
5
10
15
20
25
30

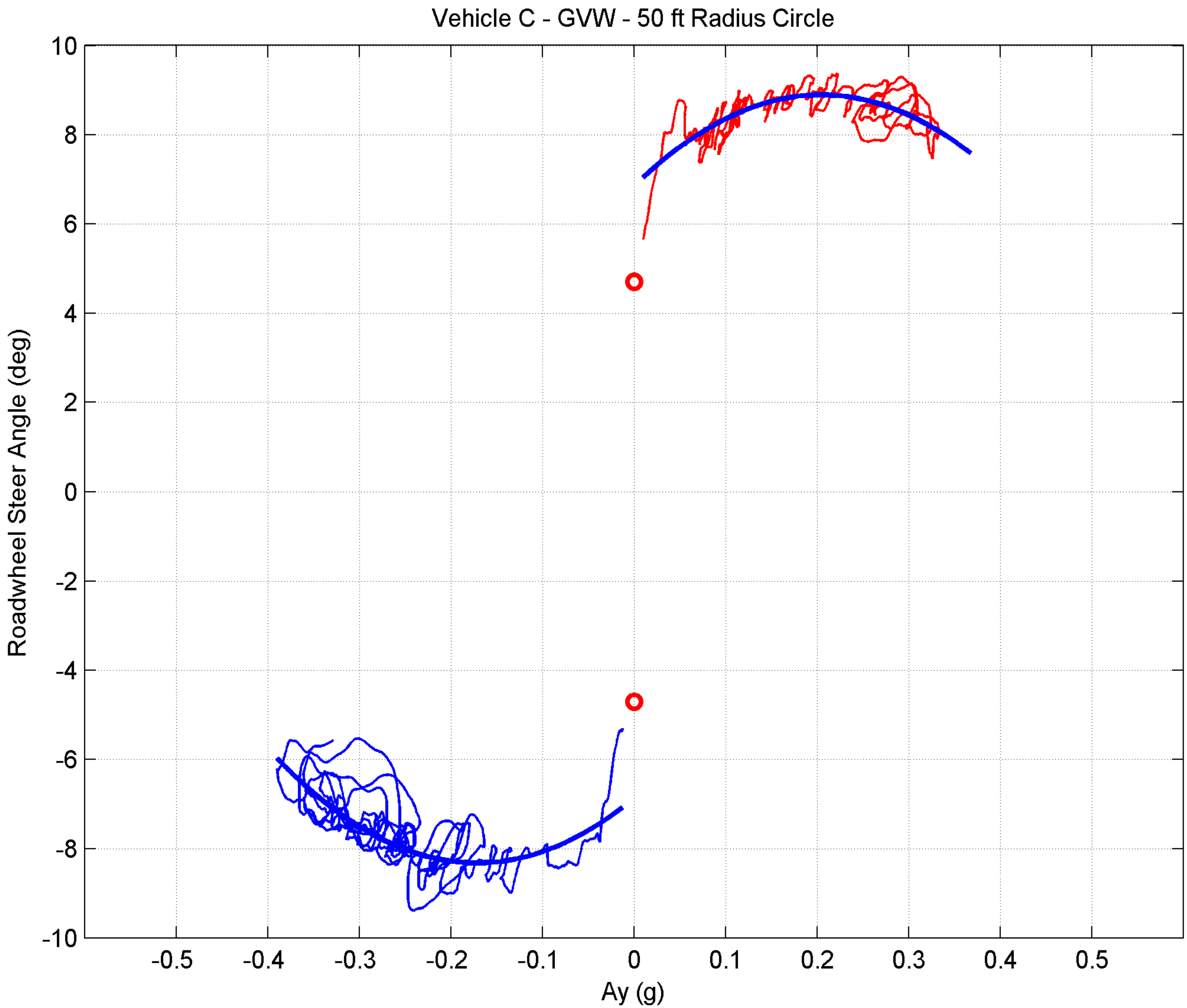


Vehicle A - GVW
15 mph Frequency Response
Ay Mag. (g/deg)
0.04
0.03
0.02
0.01
0
10^0
Roll Angle Mag. (deg/deg)
0.5
0.4
0.3
0.2
0.1
0
10^0
Ay Phase (deg)
0
-50
-100
-150
-200
10^0
Frequency (Hz)
Roll Angle Phase (deg)
-150
-200
-250
-300
-350
10^0
Frequency (Hz)

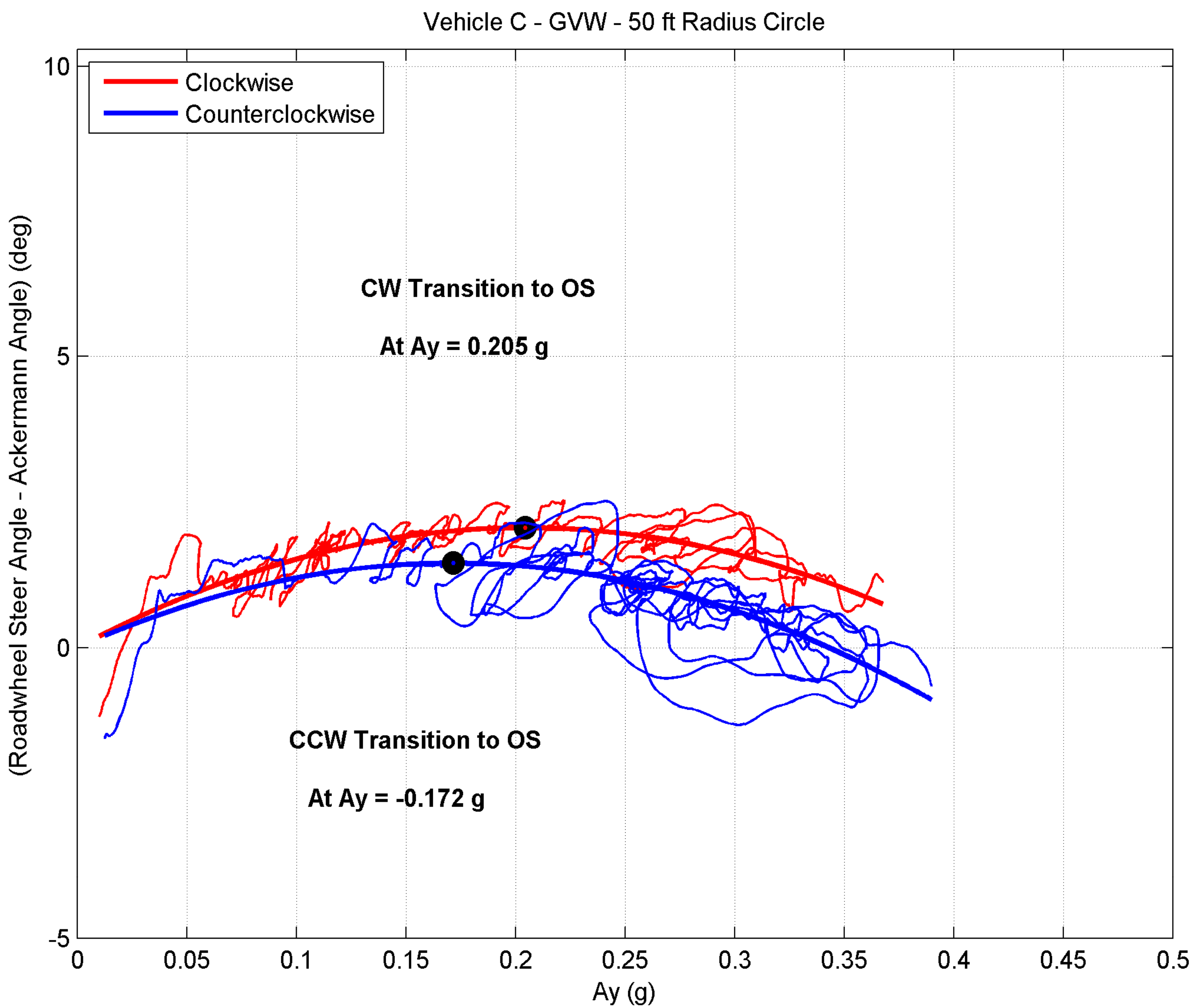


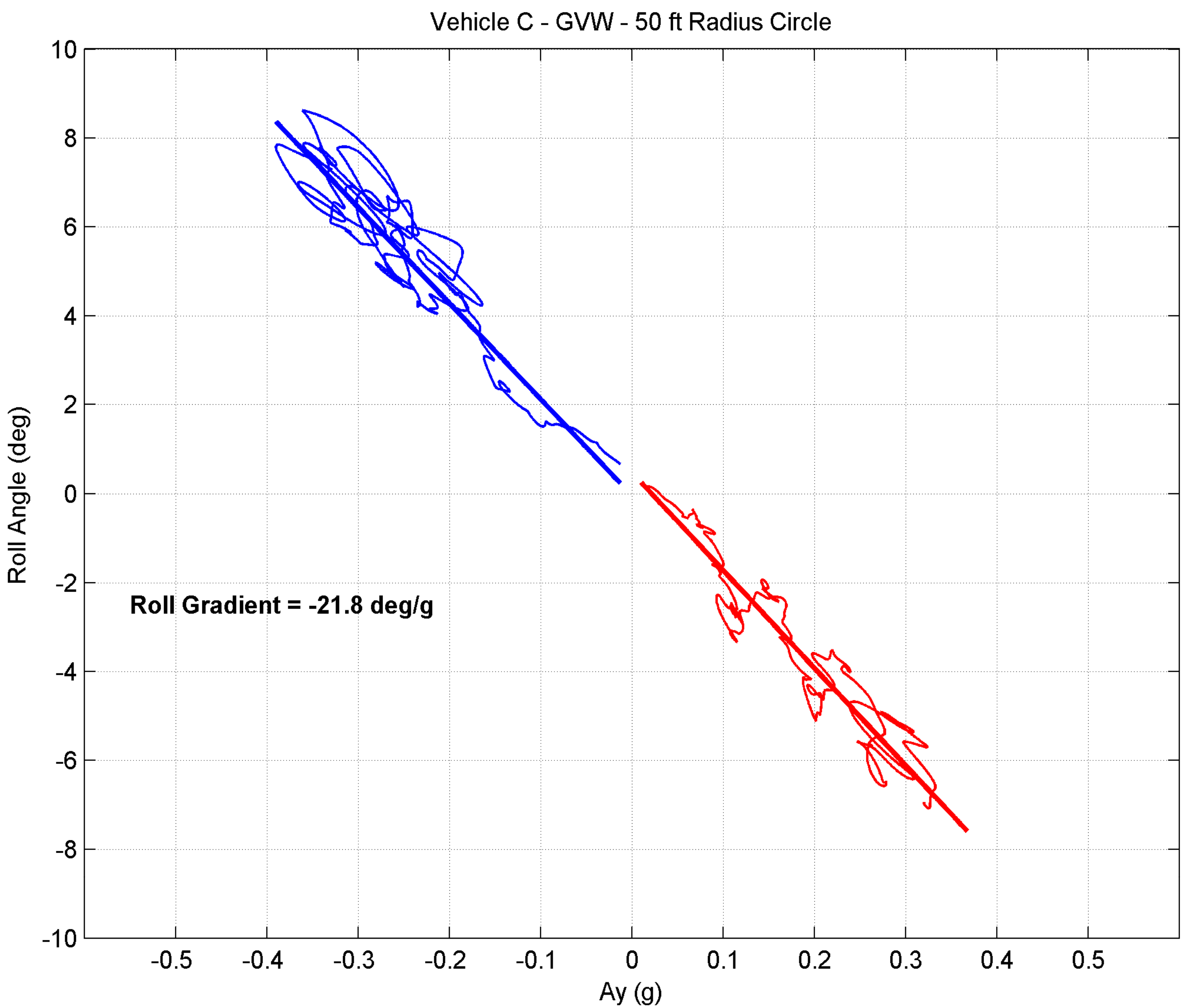
Vehicle A - GVW
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)

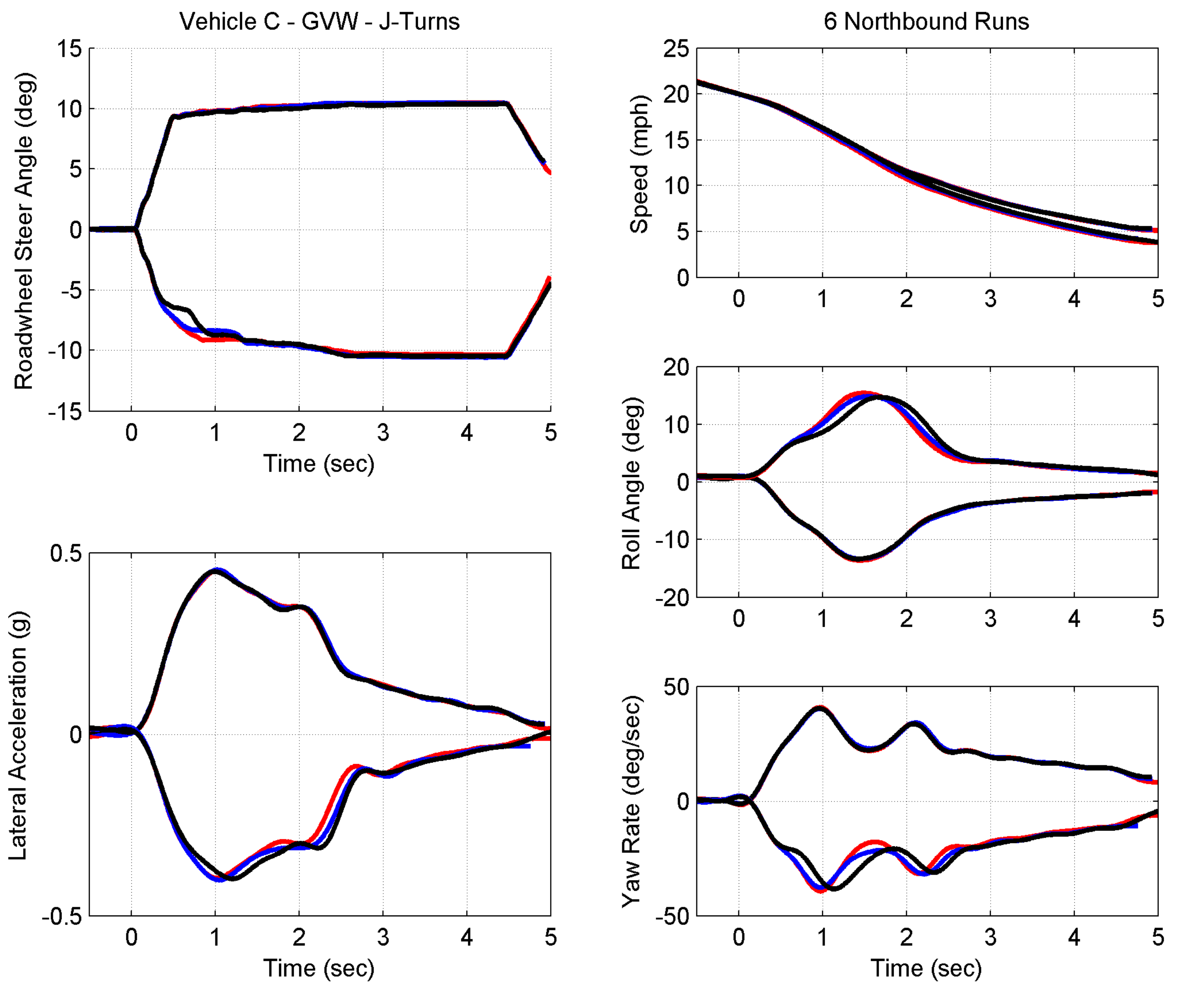

Vehicle C - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

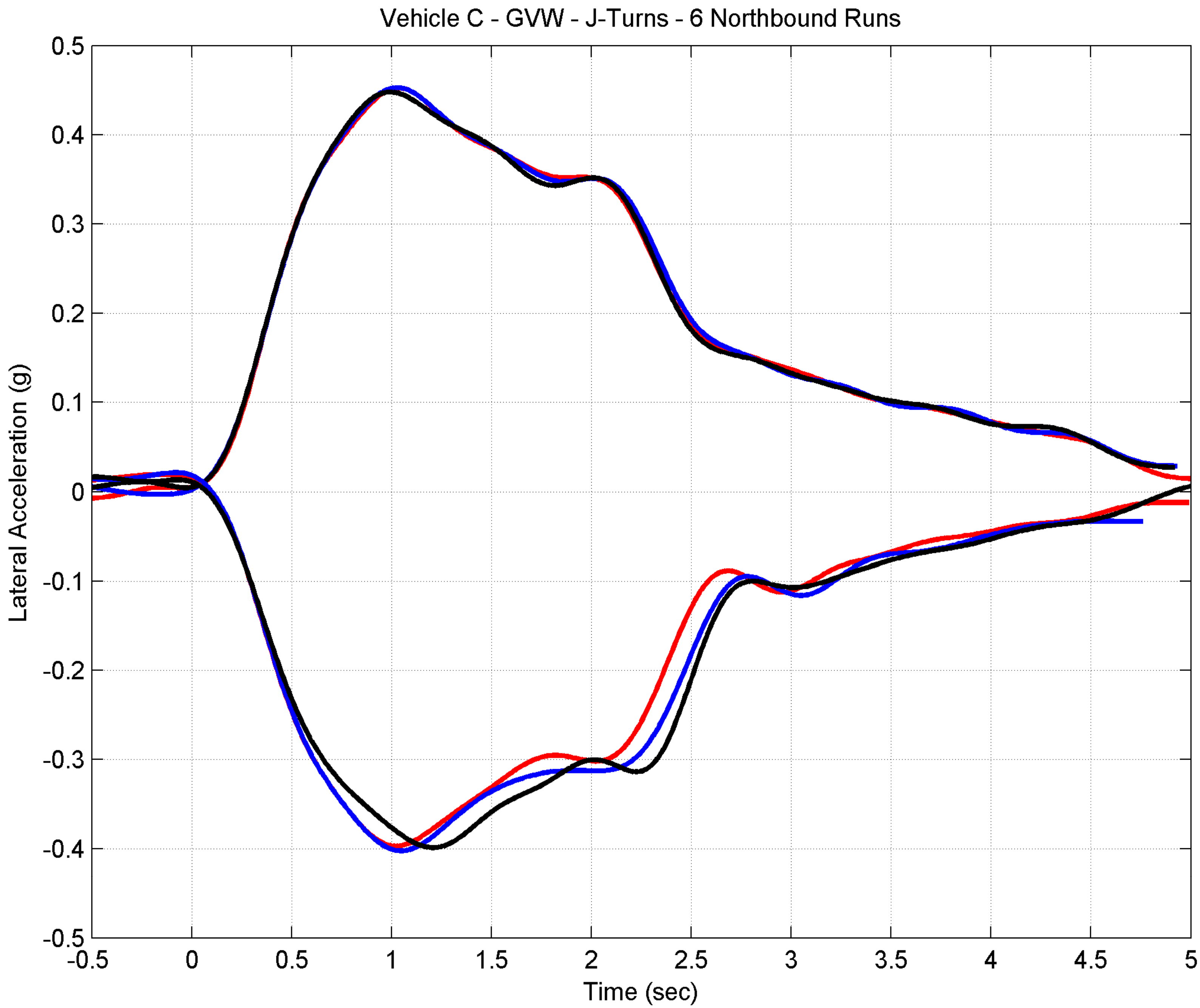


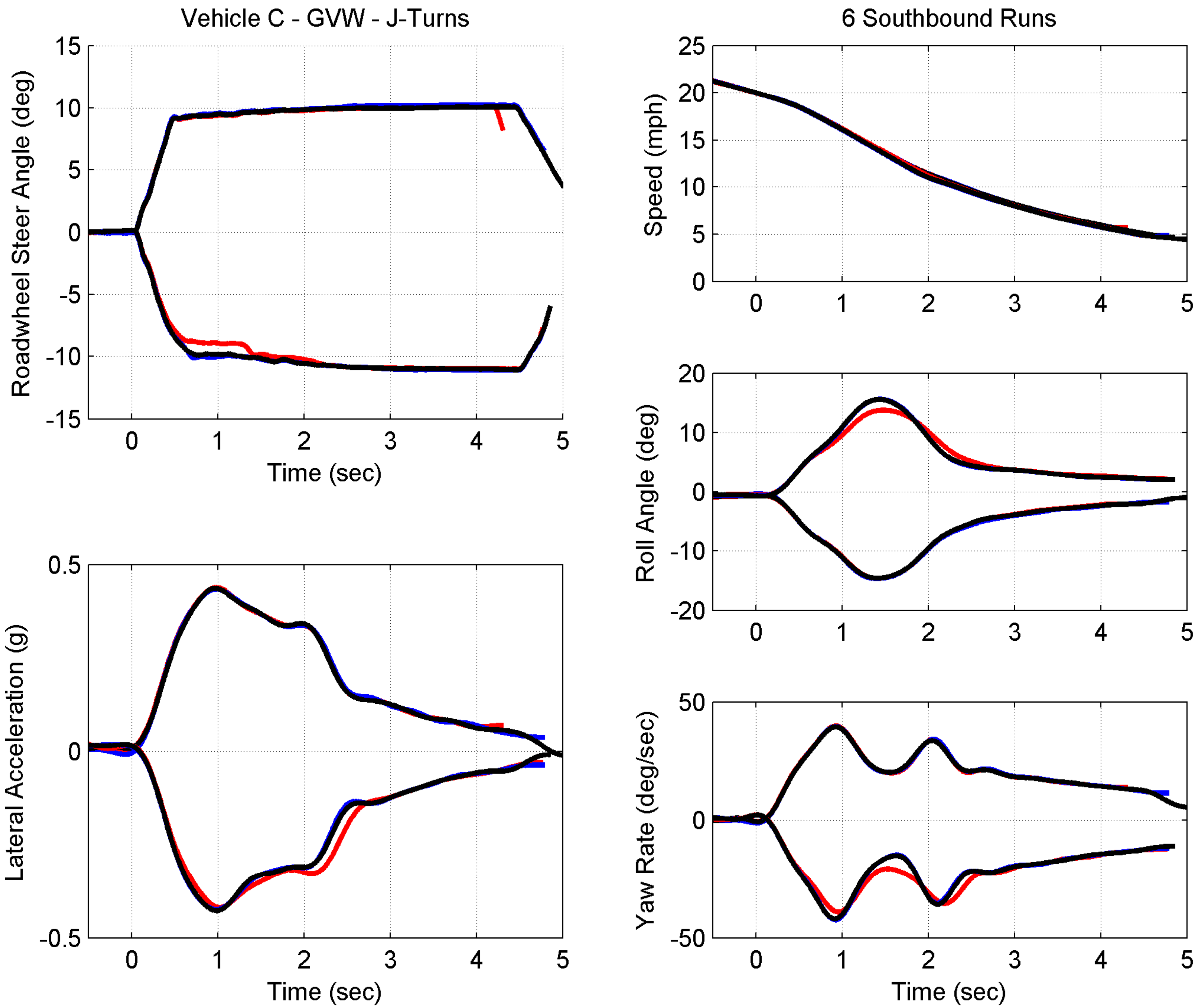
Vehicle C - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

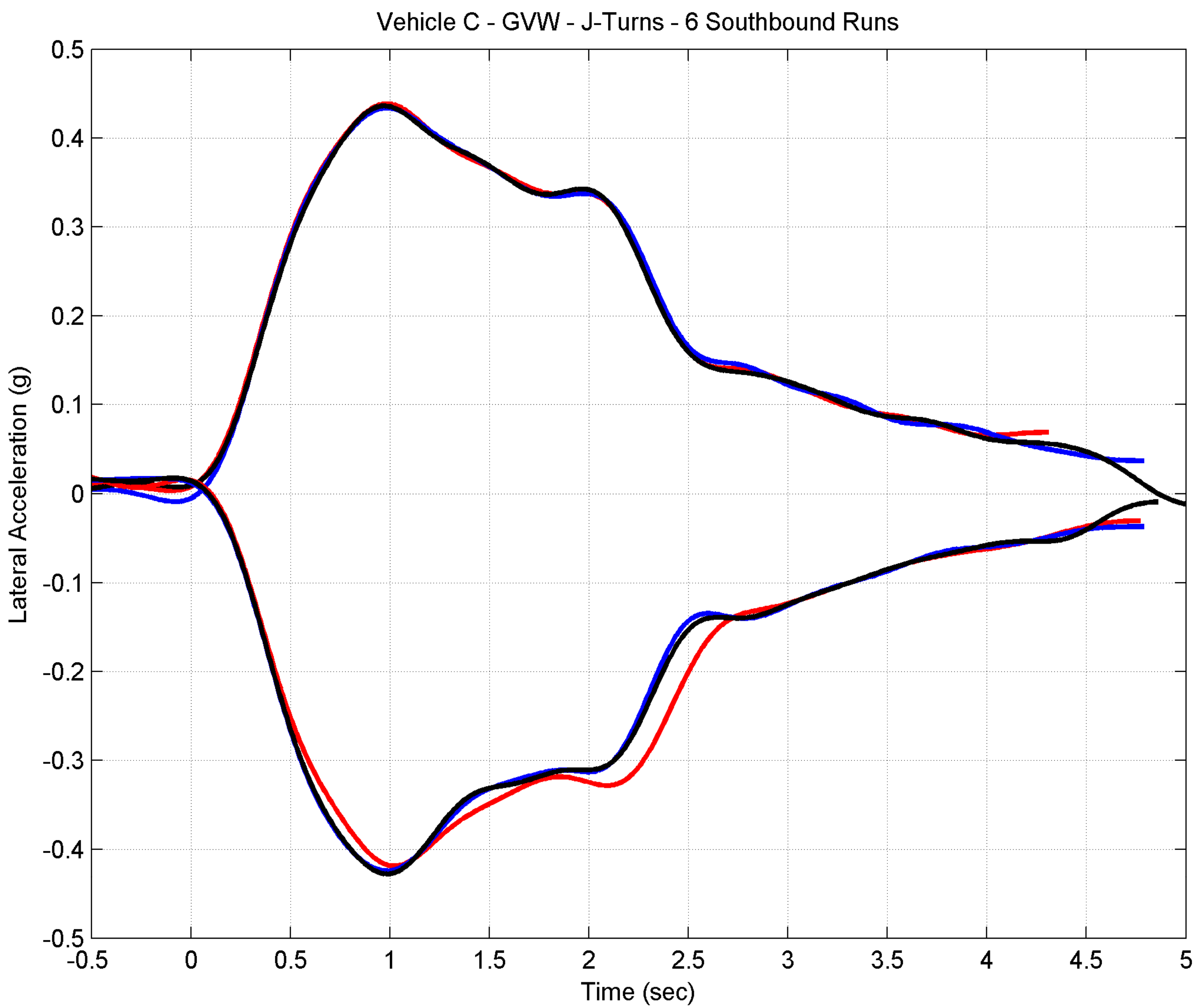

Vehicle C - GVW - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.205 g
CCW Transition to OS
At Ay = -0.172 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5


Vehicle C - GVW - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -21.8 deg/g
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5


Vehicle C - GVW - J-Turns
6 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle C - GVW - J-Turns - 6 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle C - GVW - J-Turns
6 Southbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



Vehicle C - GVW - J-Turns - 6 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle C - GVW

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

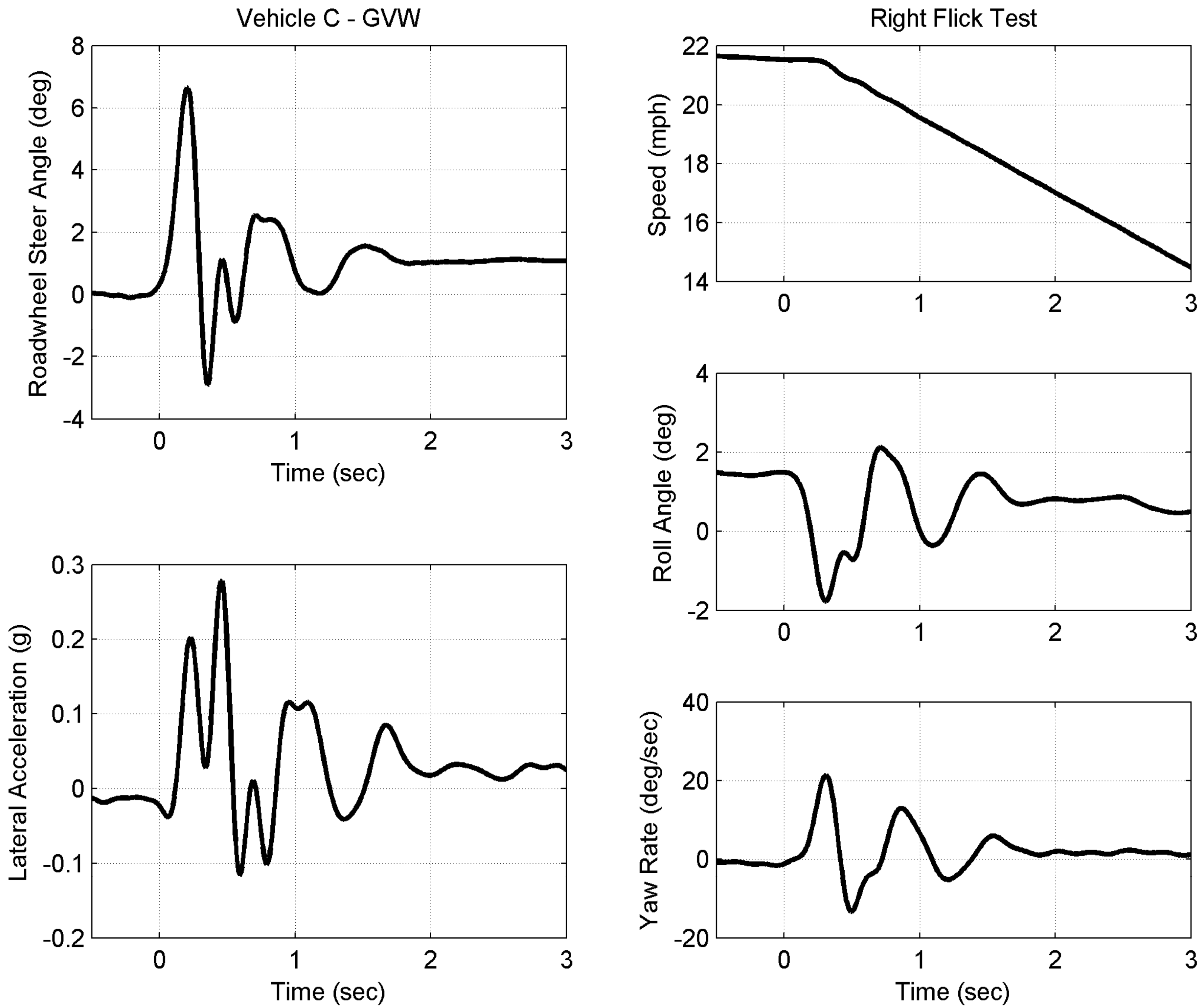
Run Number	Northbound Right Turns	Northbound Left Turns	Average of 6 Northbound Runns
1	0.4524	-0.3971	
2	0.4529	-0.4024	
3	0.4480	-0.3988	
Mean Value of 3 Runs	0.4511	-0.3994	**0.4253**
Standard Deviation of 3 Runs	0.003	0.003	

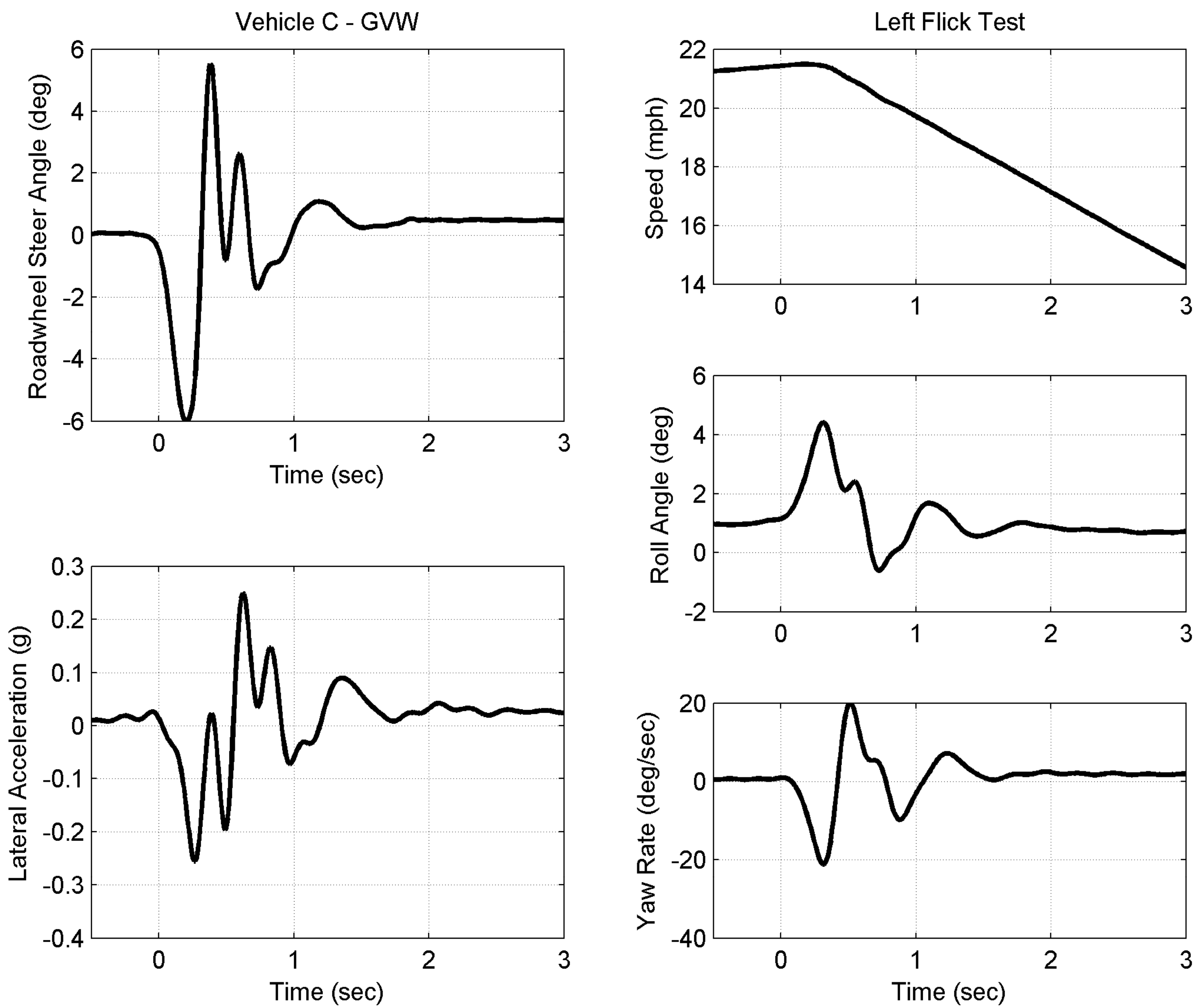
Run Number	Southbound Right Turns	Southbound Left Turns	Average of 6 Southbound Runs
1	0.4386	-0.4189	
2	0.4339	-0.4243	
3	0.4363	-0.4278	
Mean Value of 3 Runs	0.4363	-0.4236	**0.4299**
Standard Deviation of 3 Runs	0.002	0.004	

Average of All 12 Runs

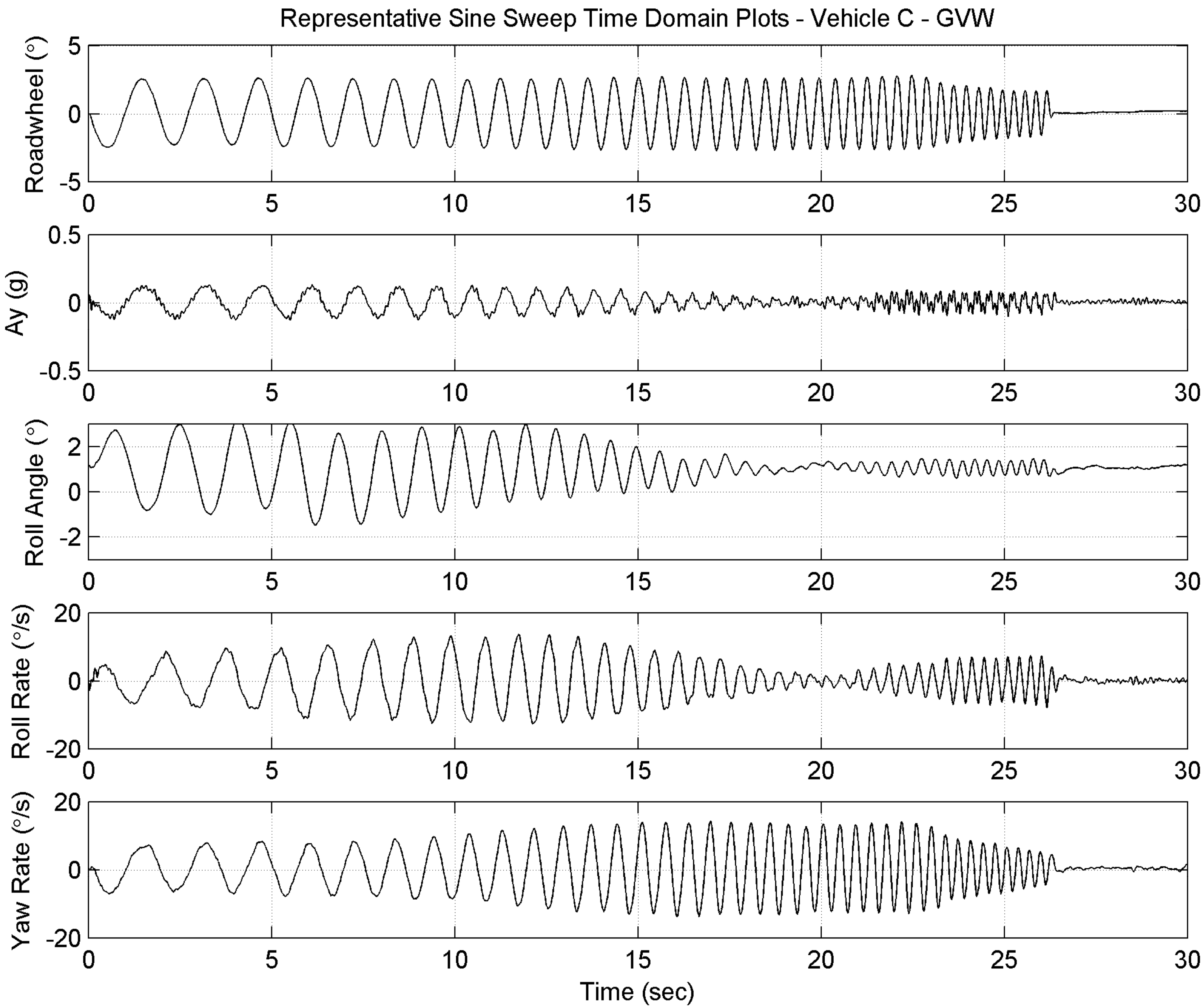
0.428

Threshold Ay

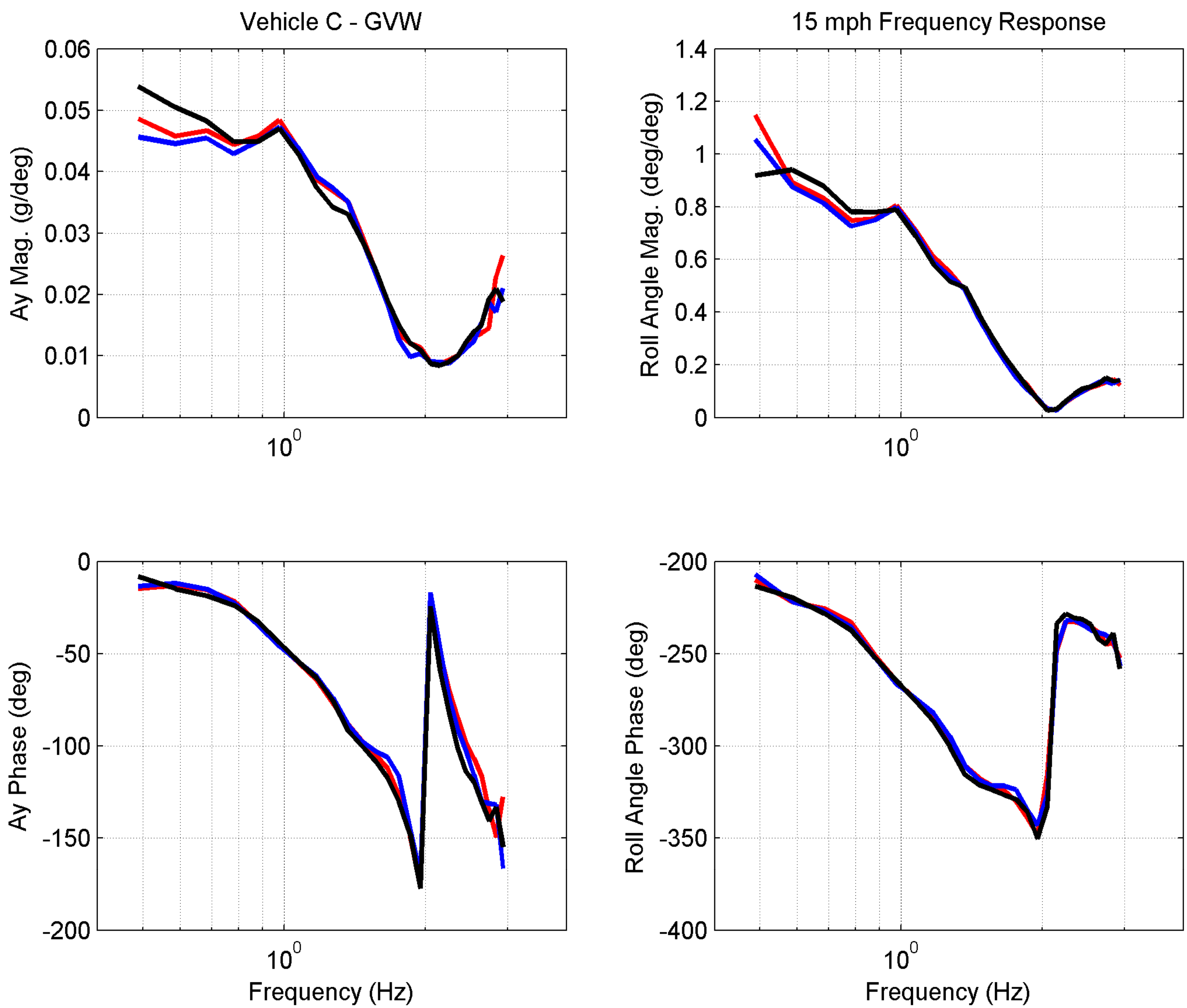

Vehicle C - GVW
Right Flick Test
Roadwheel Steer Angle (deg)
8
6
4
2
0
-2
-4
0
1
2
3
Time (sec)
Speed (mph)
22
20
18
16
14
Roll Angle (deg)
4
2
0
-2
Lateral Acceleration (g)
0.3
0.2
0.1
0
-0.1
-0.2
Yaw Rate (deg/sec)
40
20
0
-20



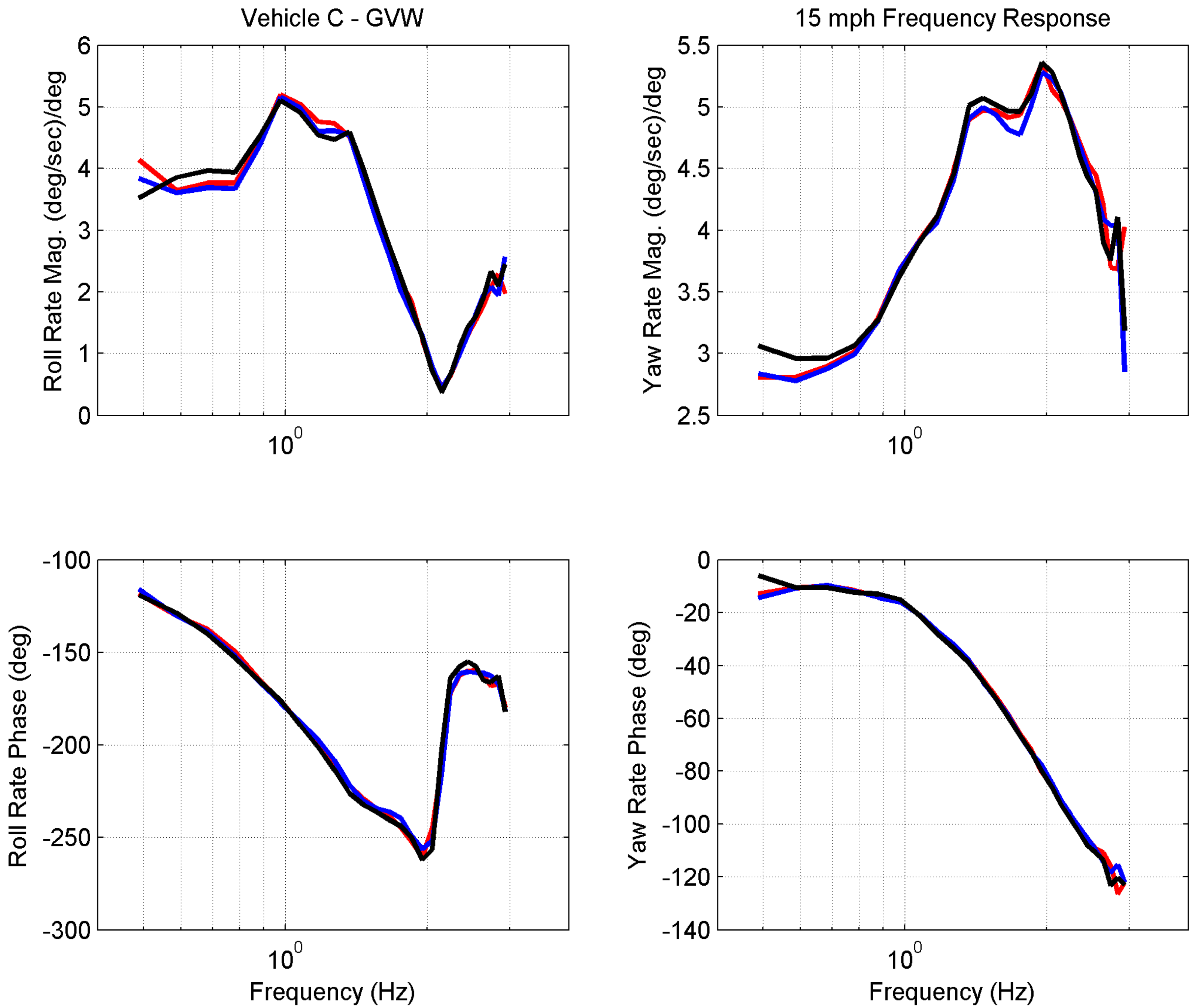
Vehicle C - GVW
Left Flick Test
Roadwheel Steer Angle (deg)
6
4
2
0
-2
-4
-6
0
1
2
3
Time (sec)
Speed (mph)
22
20
18
16
14
Roll Angle (deg)
-2
Lateral Acceleration (g)
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
Yaw Rate (deg/sec)
20
-20
-40

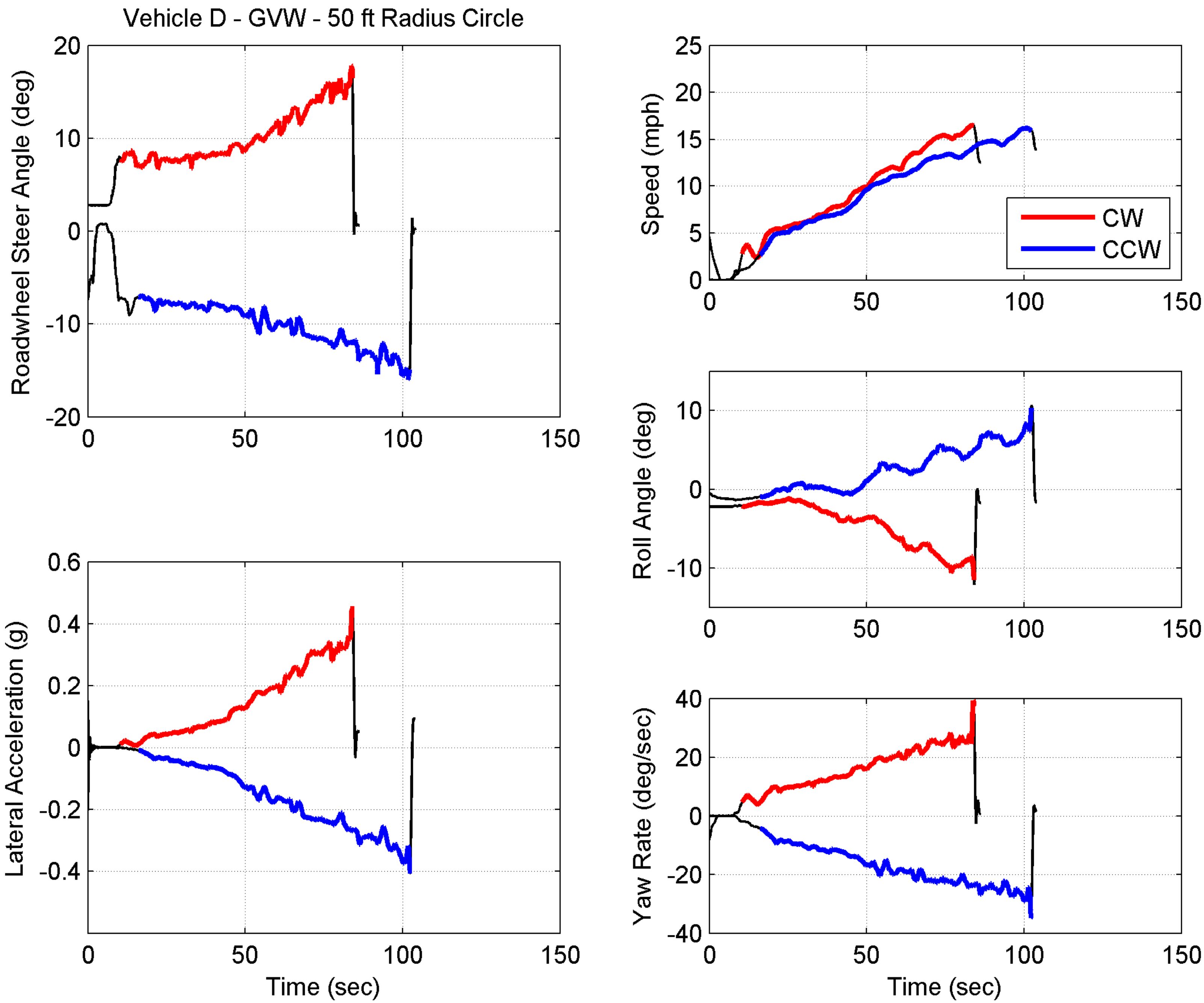


Representative Sine Sweep Time Domain Plots - Vehicle C - GVW
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

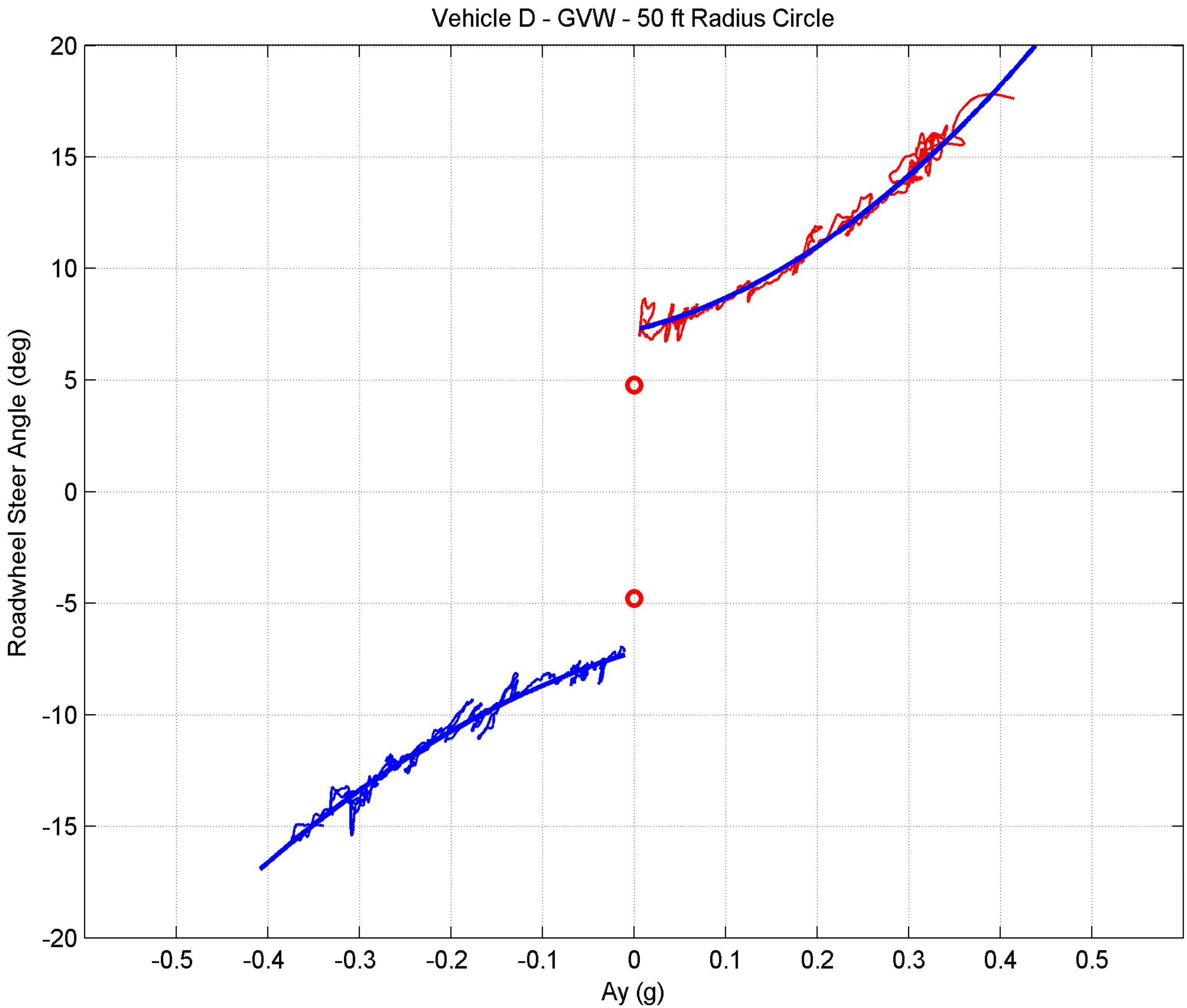


Vehicle C - GVW
15 mph Frequency Response
Ay Mag. (g/deg)
0.06
0.05
0.04
0.03
0.02
0.01
0
Roll Angle Mag. (deg/deg)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Ay Phase (deg)
0
-50
-100
-150
-200
Roll Angle Phase (deg)
-200
-250
-300
-350
-400
10^0
Frequency (Hz)

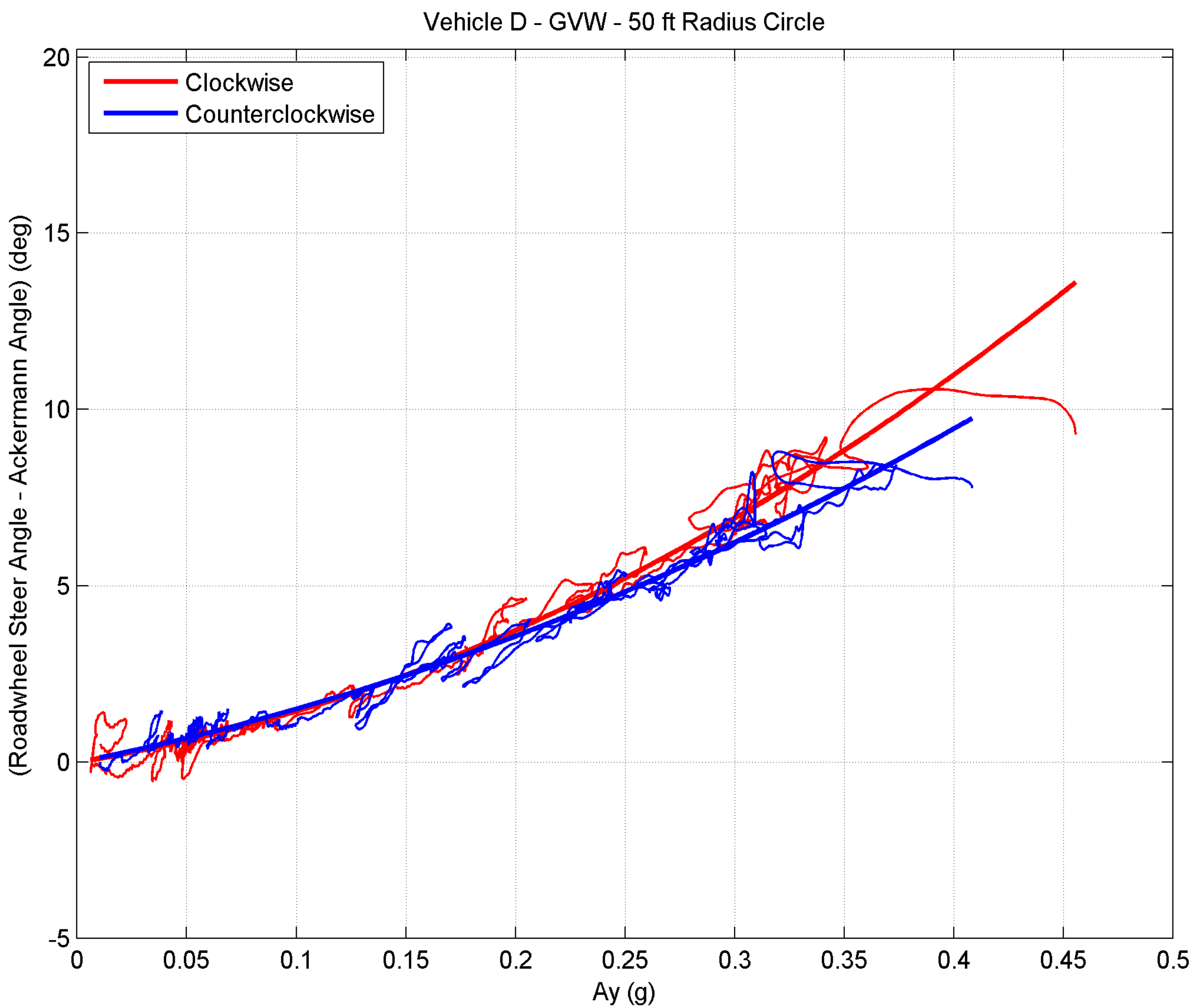

Vehicle C - GVW
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
6
5
4
3
2
1
0
5.5
5
4.5
4
3.5
3
2.5
-100
-150
-200
-250
-300
0
-20
-40
-60
-80
-100
-120
-140
10^0



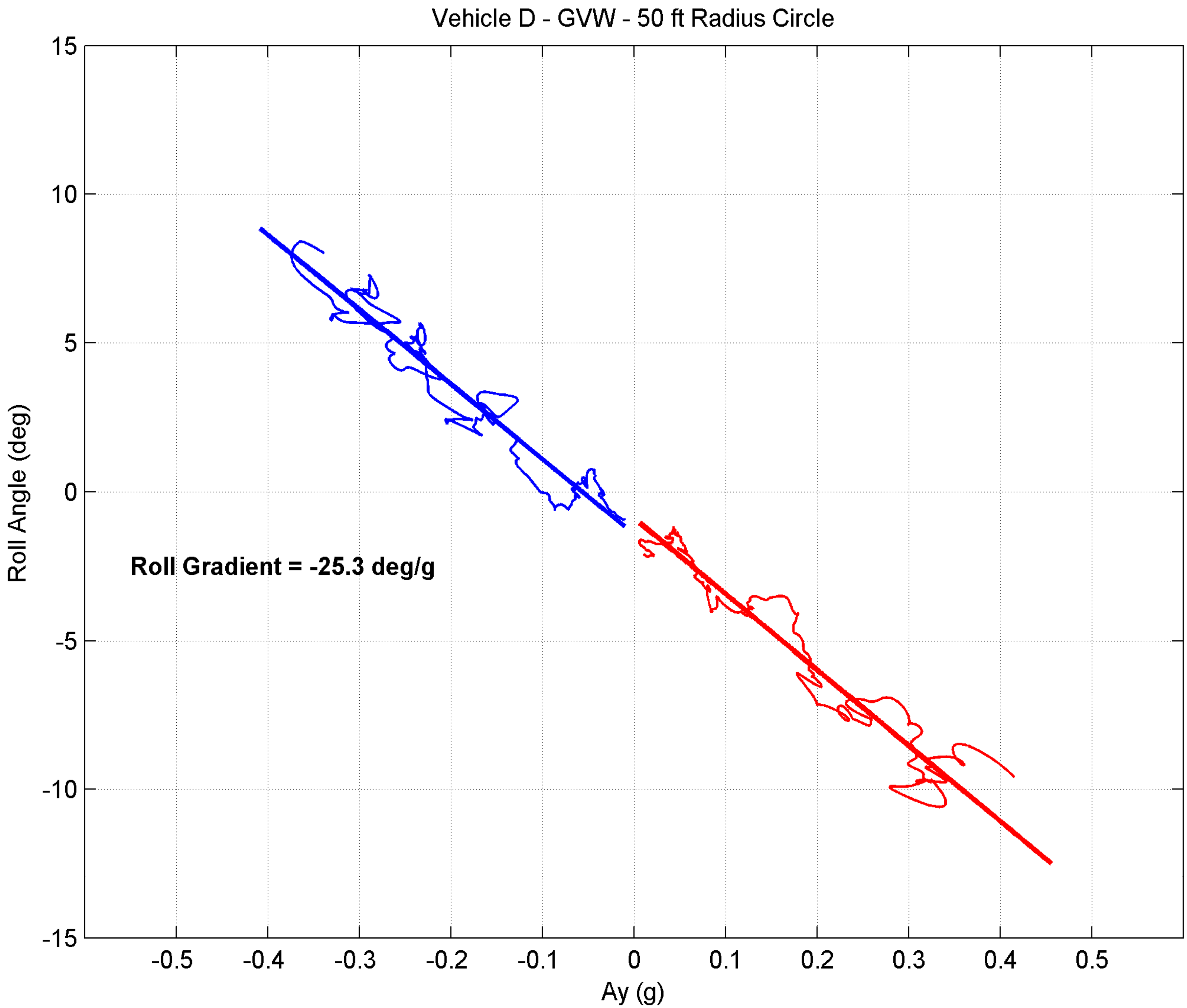
Vehicle D - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



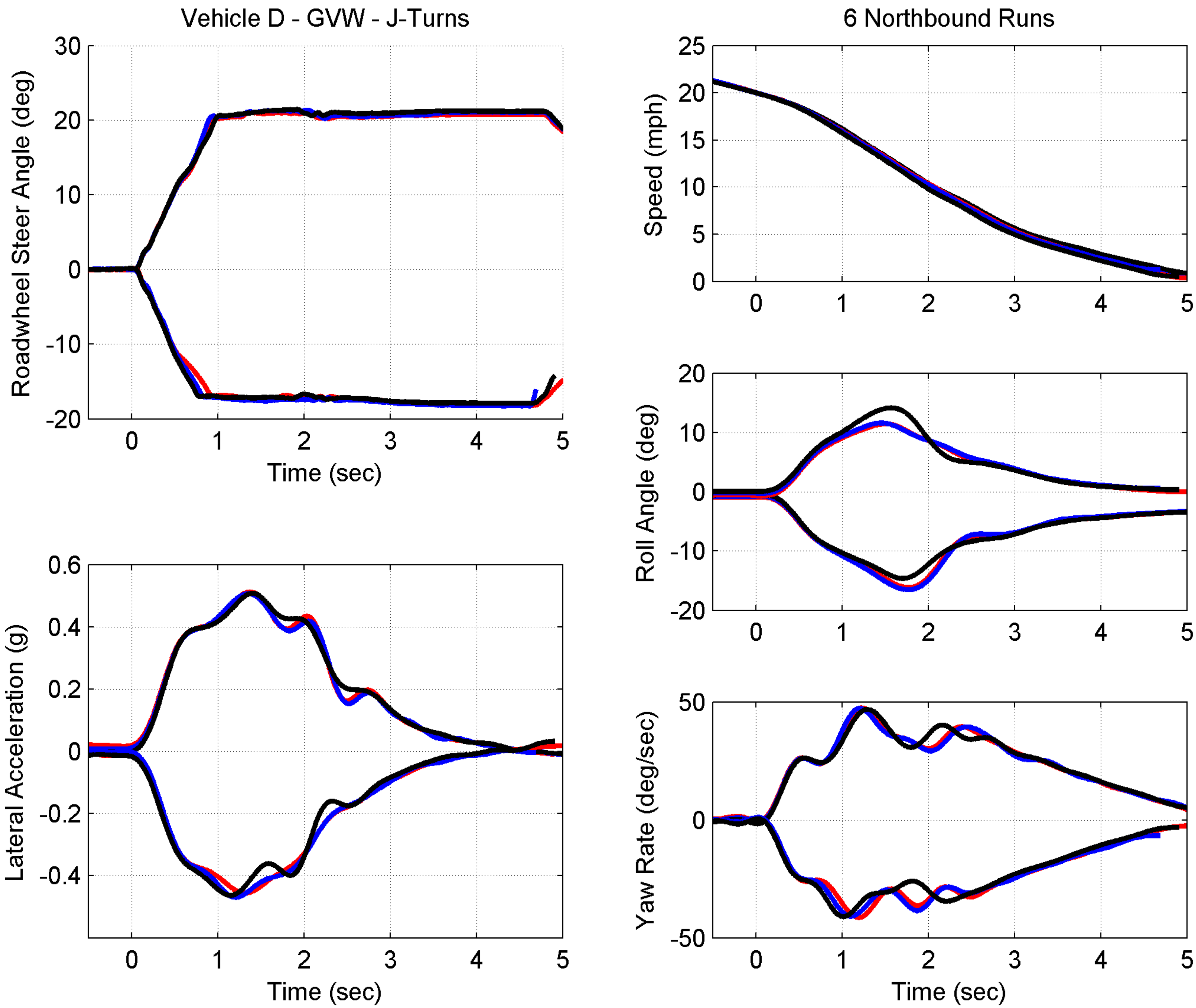
Vehicle D - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
20
15
10
5
0
-5
-10
-15
-20
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5



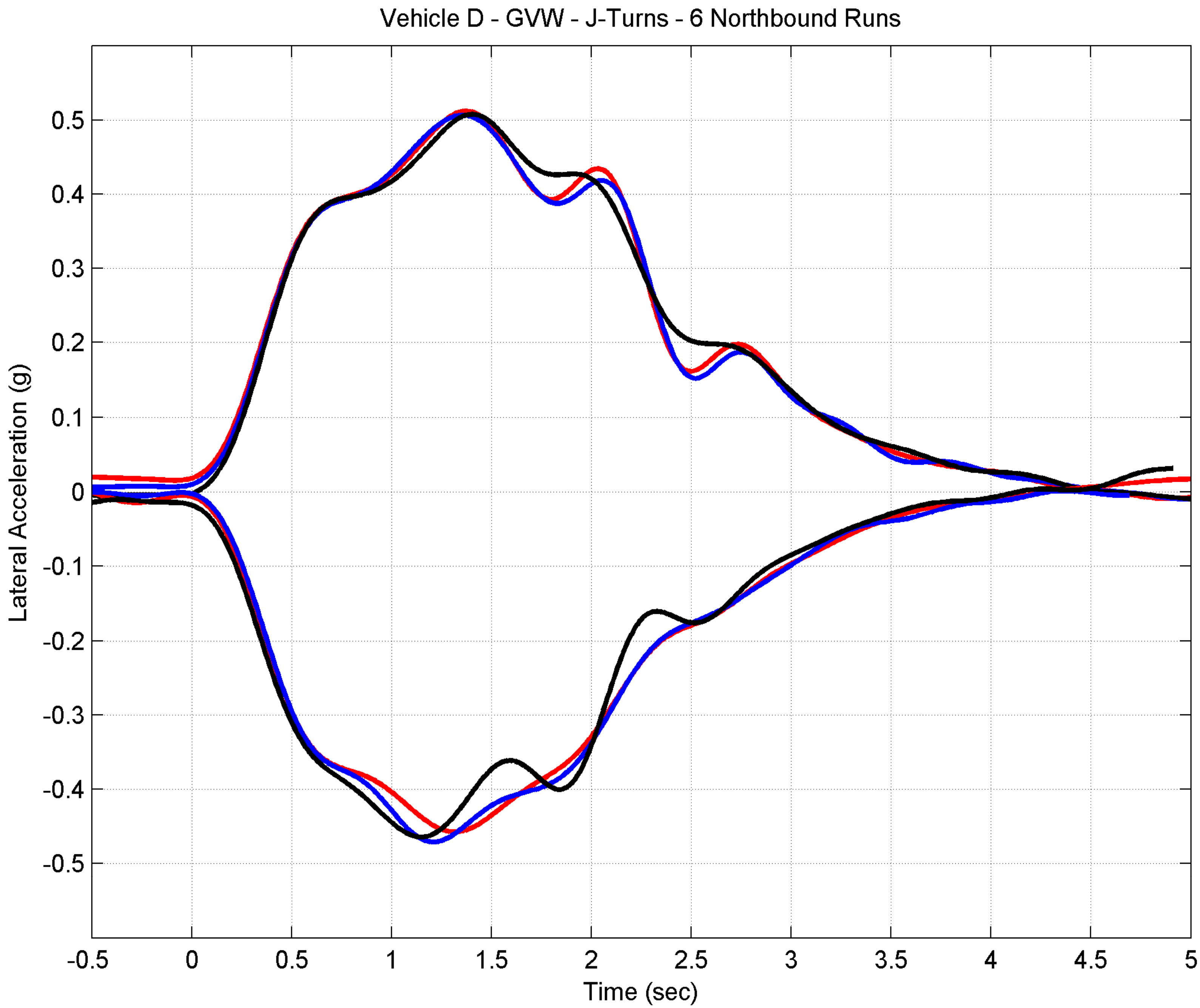
Vehicle D - GVW - 50 ft Radius Circle
Clockwise
Counterclockwise
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
20
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

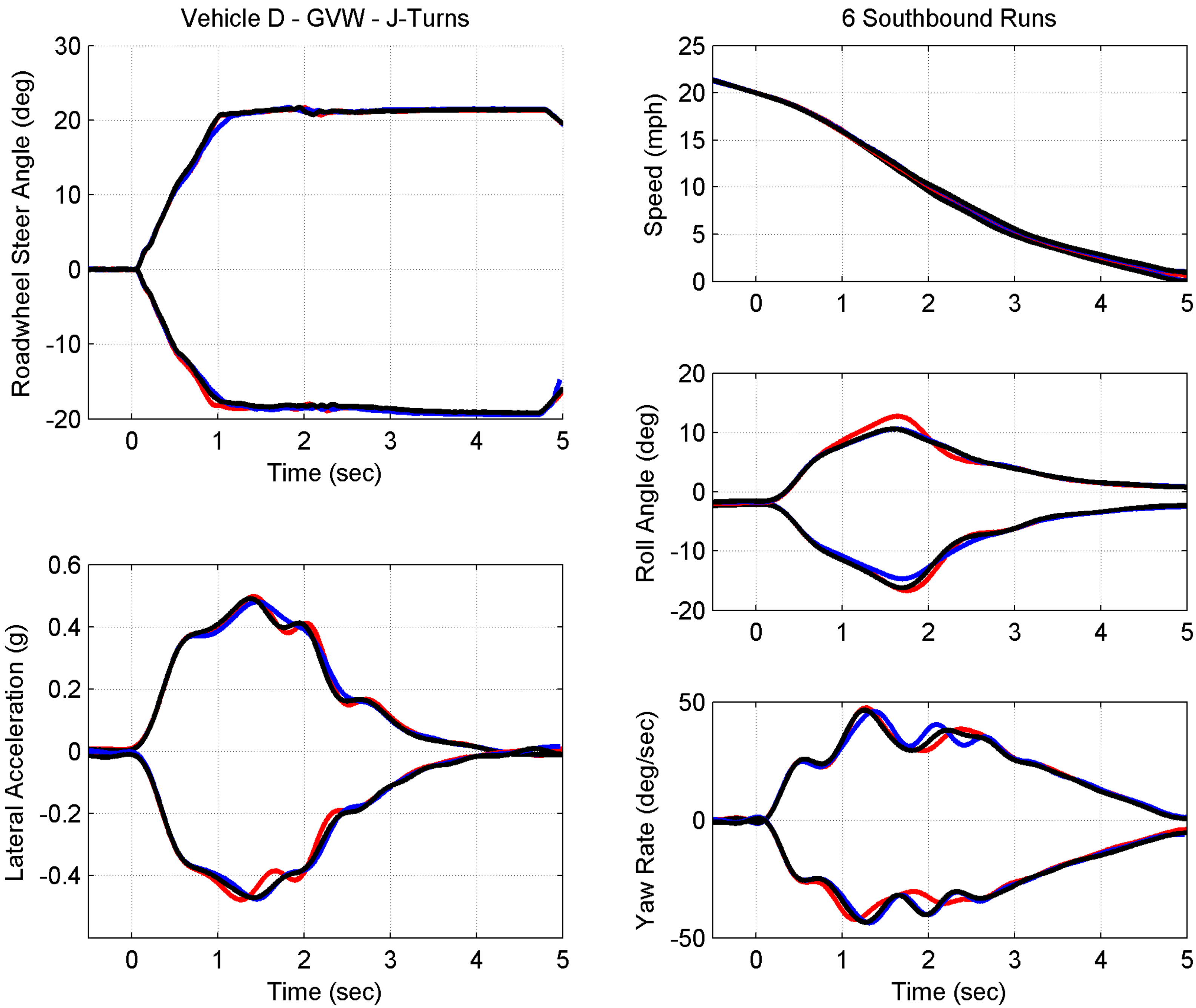


Vehicle D - GVW - 50 ft Radius Circle
15
10
5
0
-5
-10
-15
Roll Angle (deg)
Roll Gradient = -25.3 deg/g
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

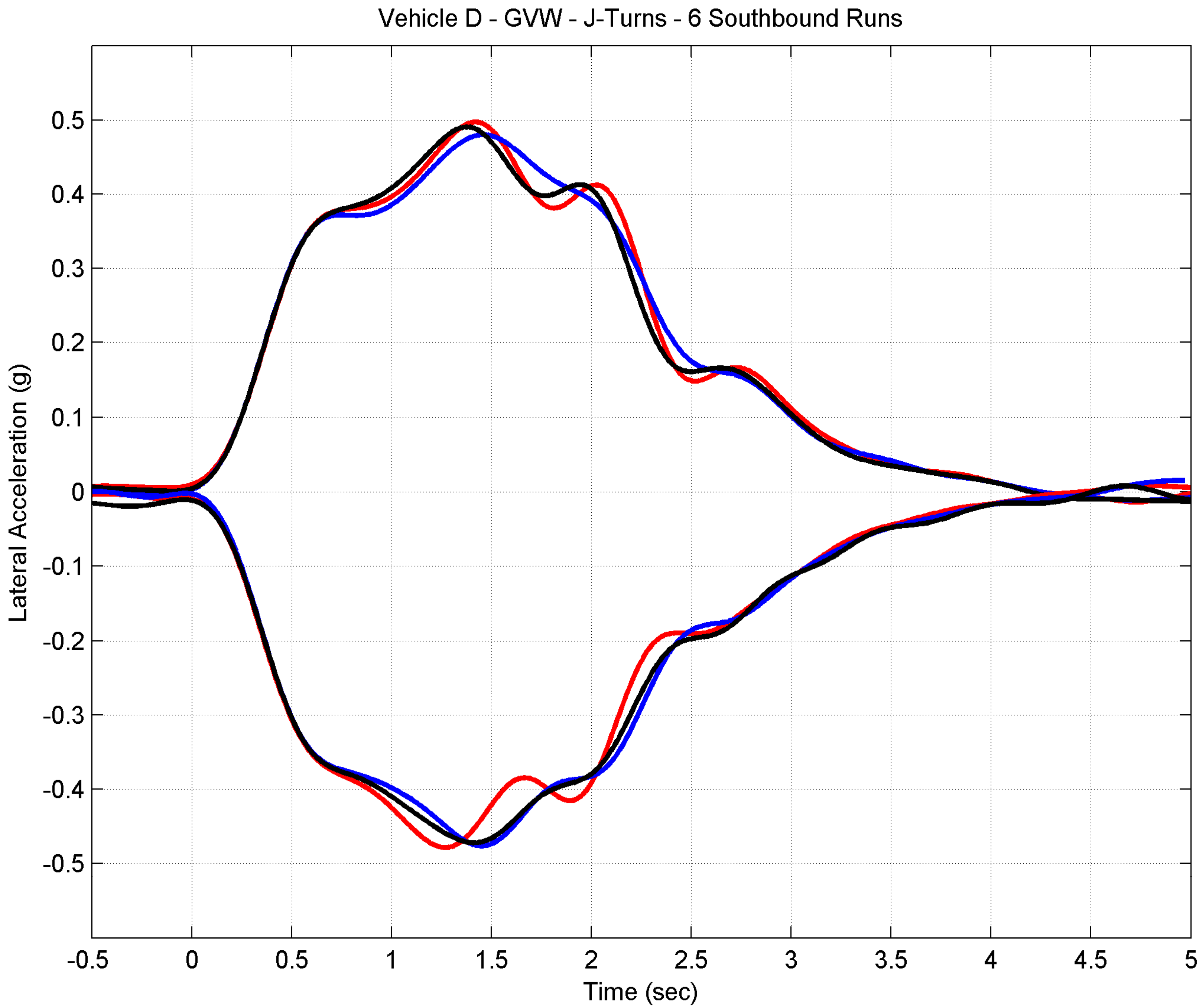


Vehicle D - GVW - J-Turns
6 Northbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)


Vehicle D - GVW - J-Turns - 6 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle D - GVW - J-Turns
6 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle D - GVW - J-Turns - 6 Southbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle D - GVW

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

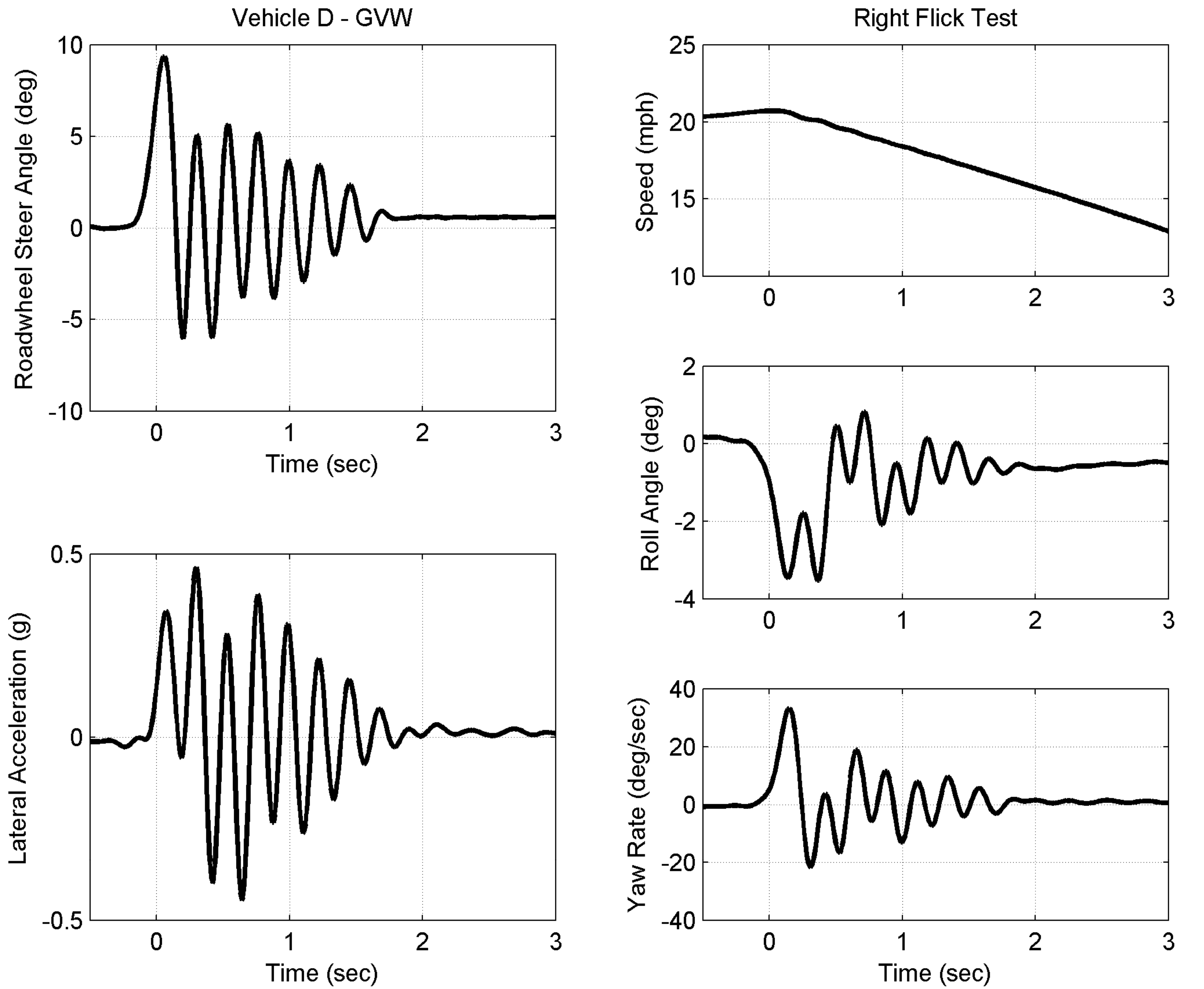
Run Number	Northbound Right Turns	Northbound Left Turns	Average of 6 Northbound Runns
1	0.5121	-0.4573	
2	0.5065	-0.4709	
3	0.5077	-0.4644	
Mean Value of 3 Runs	0.5088	-0.4642	0.4865
Standard Deviation of 3 Runs	0.003	0.007	

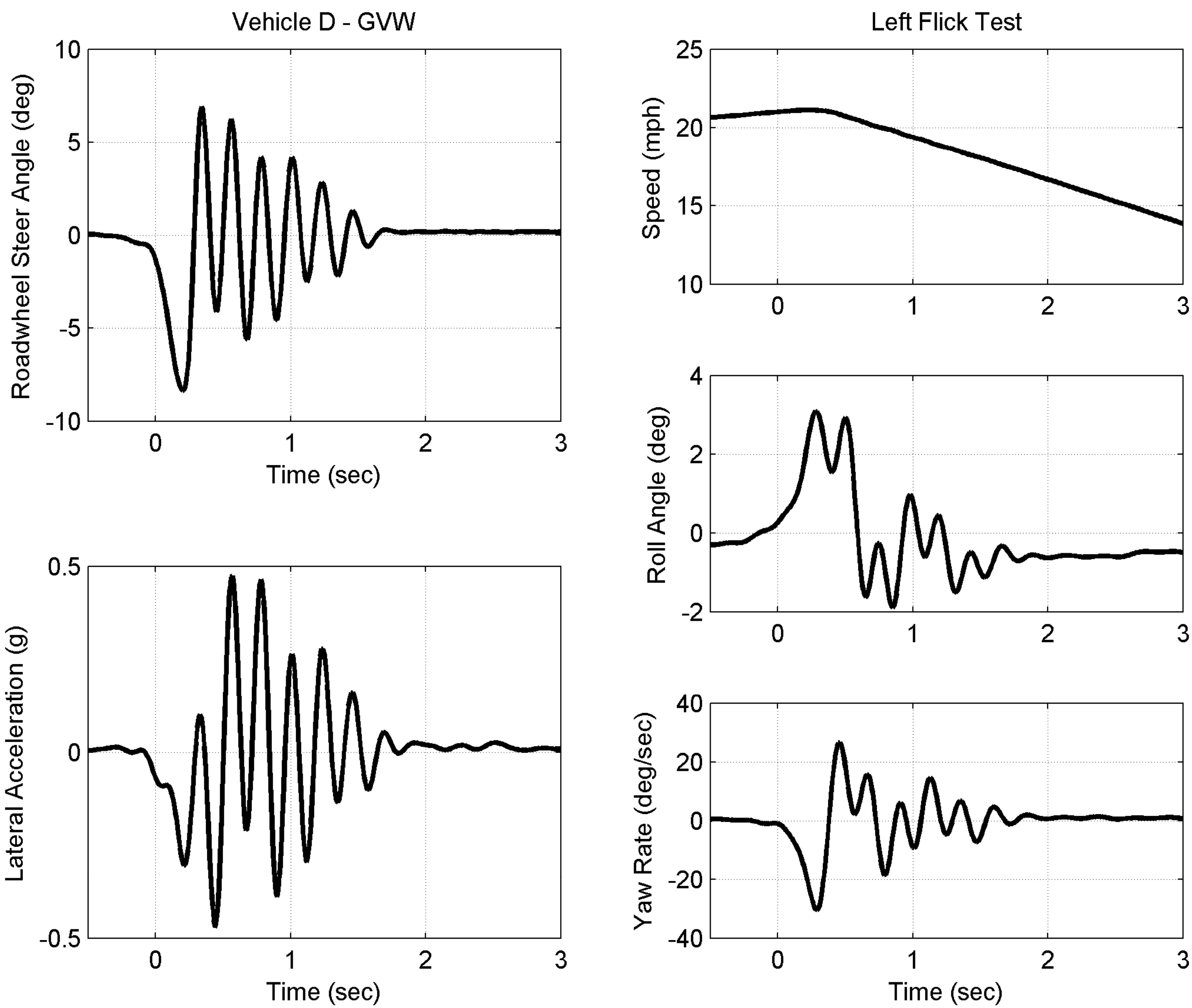
Run Number	Southbound Right Turns	Southbound Left Turns	Average of 6 Southbound Runs
1	0.4974	-0.4785	
2	0.4803	-0.4764	
3	0.4908	-0.4720	
Mean Value of 3 Runs	0.4895	-0.4756	0.4826
Standard Deviation of 3 Runs	0.009	0.003	

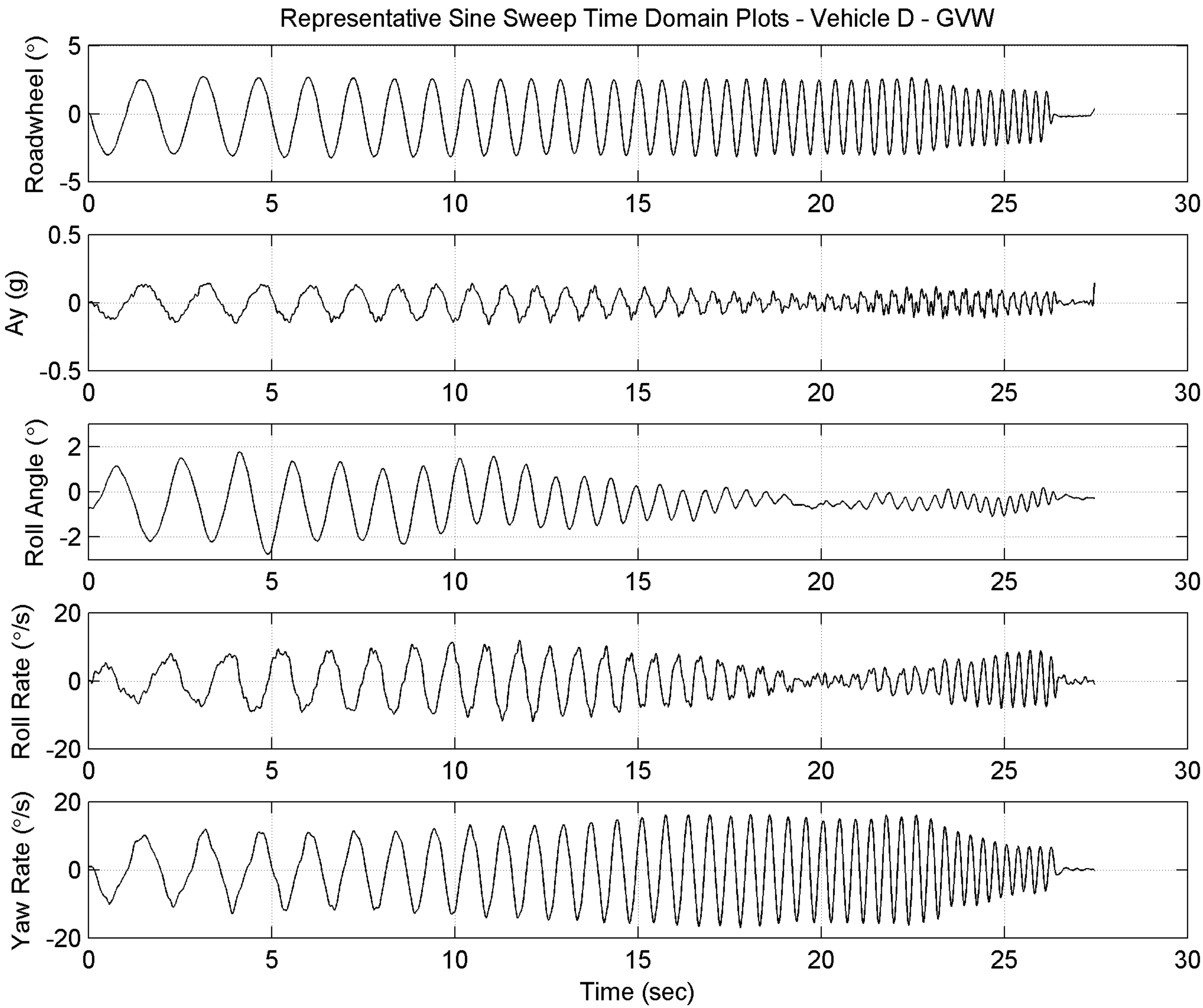
Average of All 12 Runs

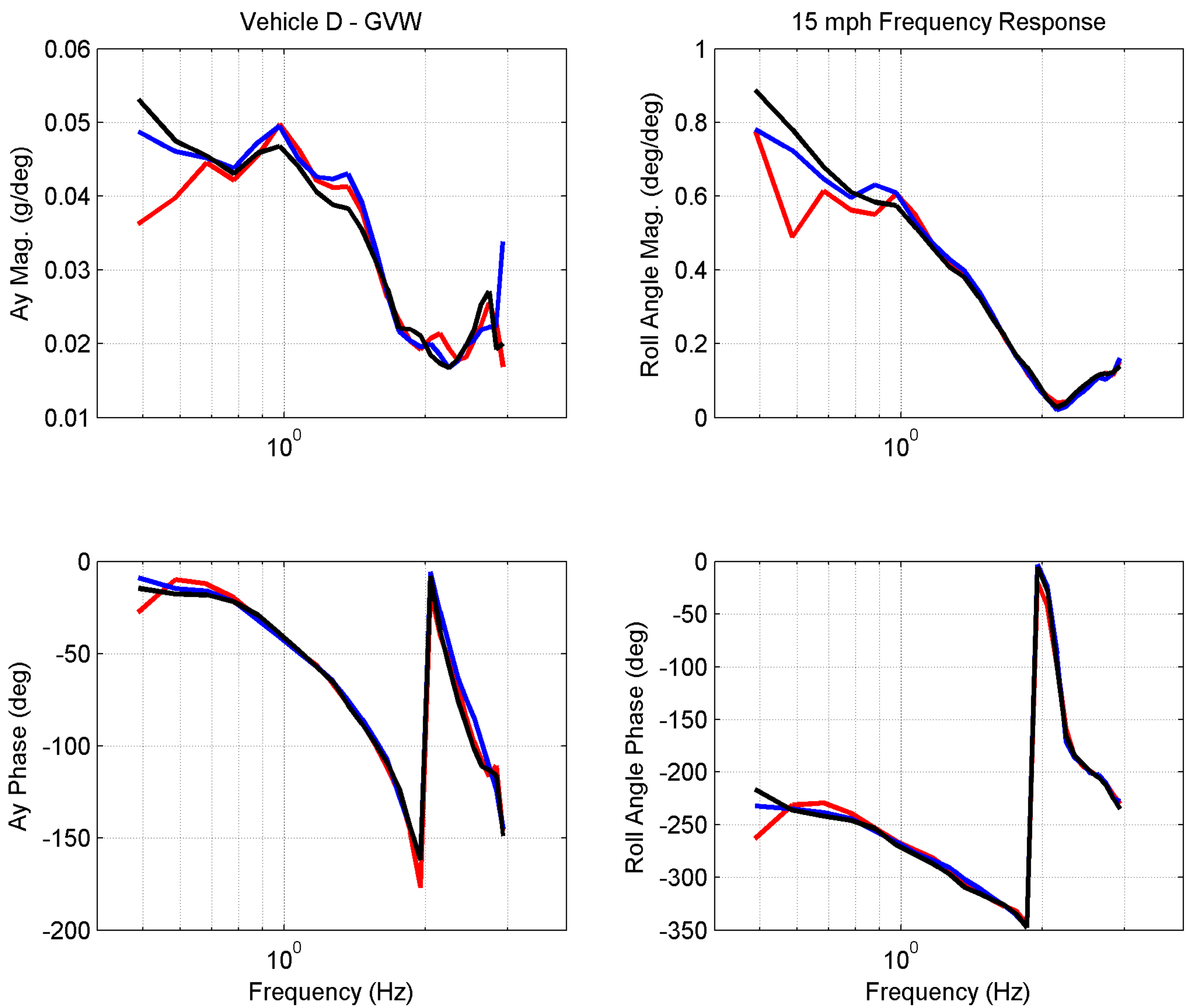
0.485

Threshold Ay

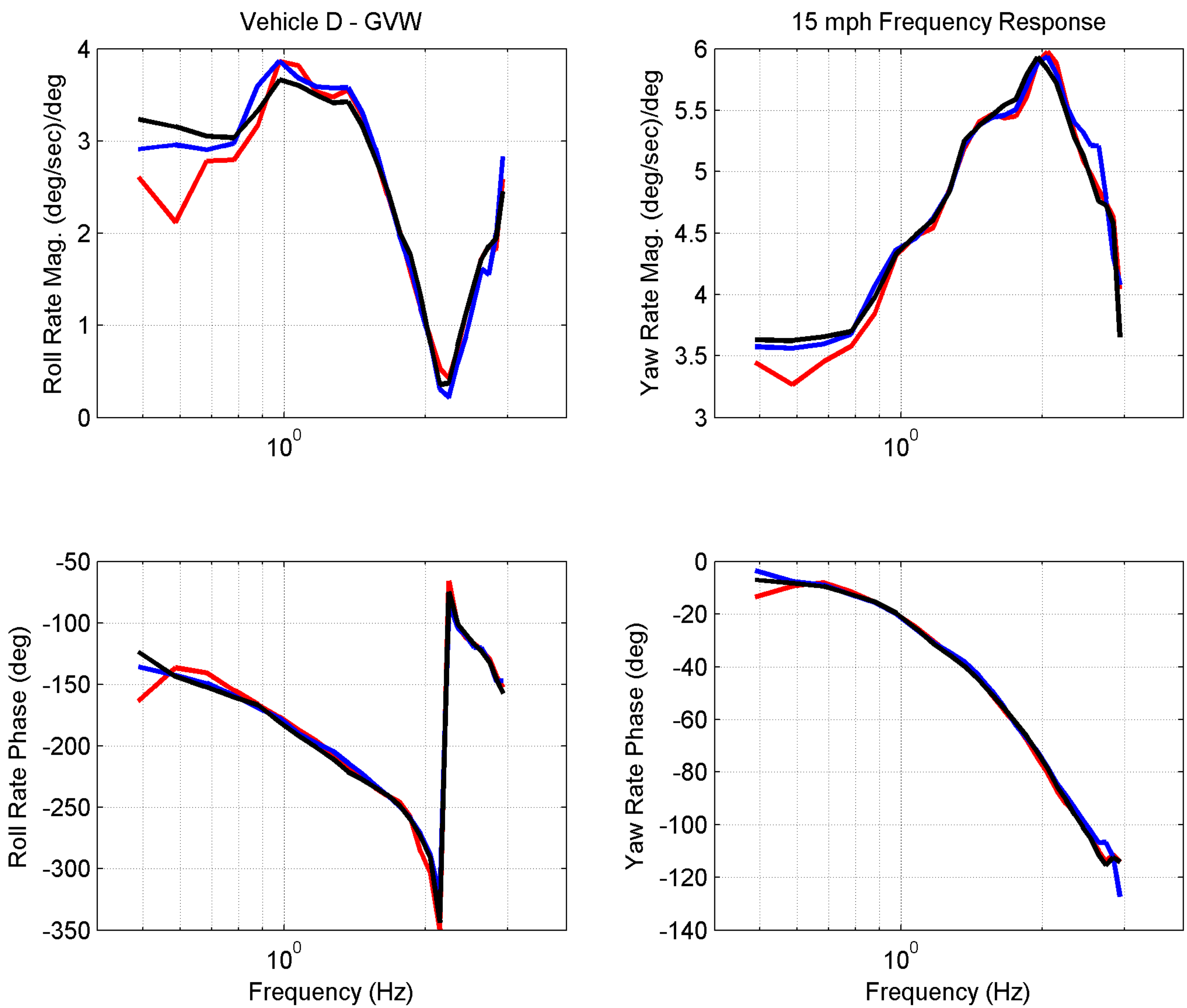

Vehicle D - GVW
Right Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
10
5
0
-5
-10
25
20
15
2
-2
-4
0.5
-0.5
40
-20
-40
1
3


Vehicle D - GVW
Left Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

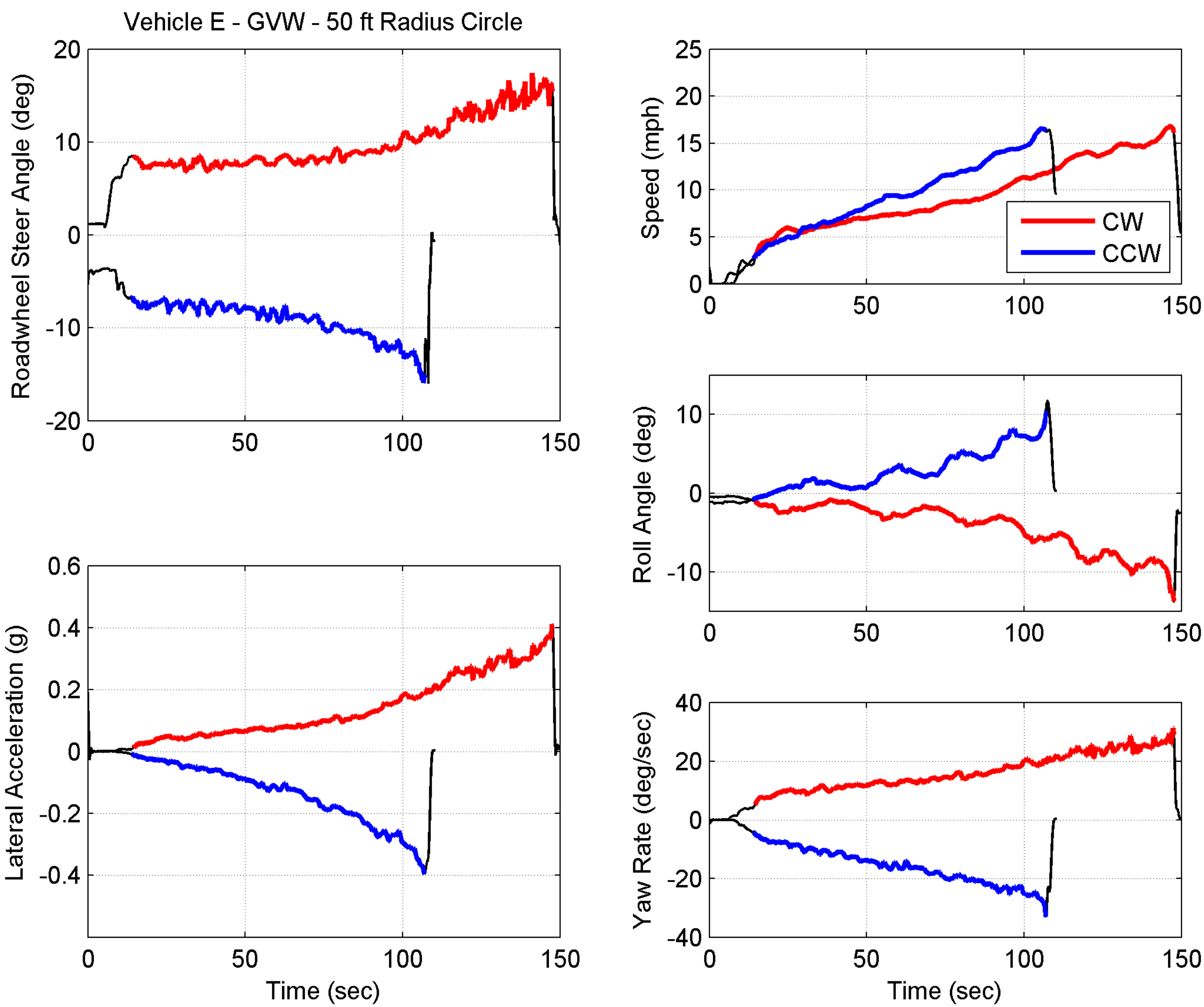

Representative Sine Sweep Time Domain Plots - Vehicle D - GVW
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)
5
0
-5
0.5
-0.5
2
-2
20
-20
10
15
25
30



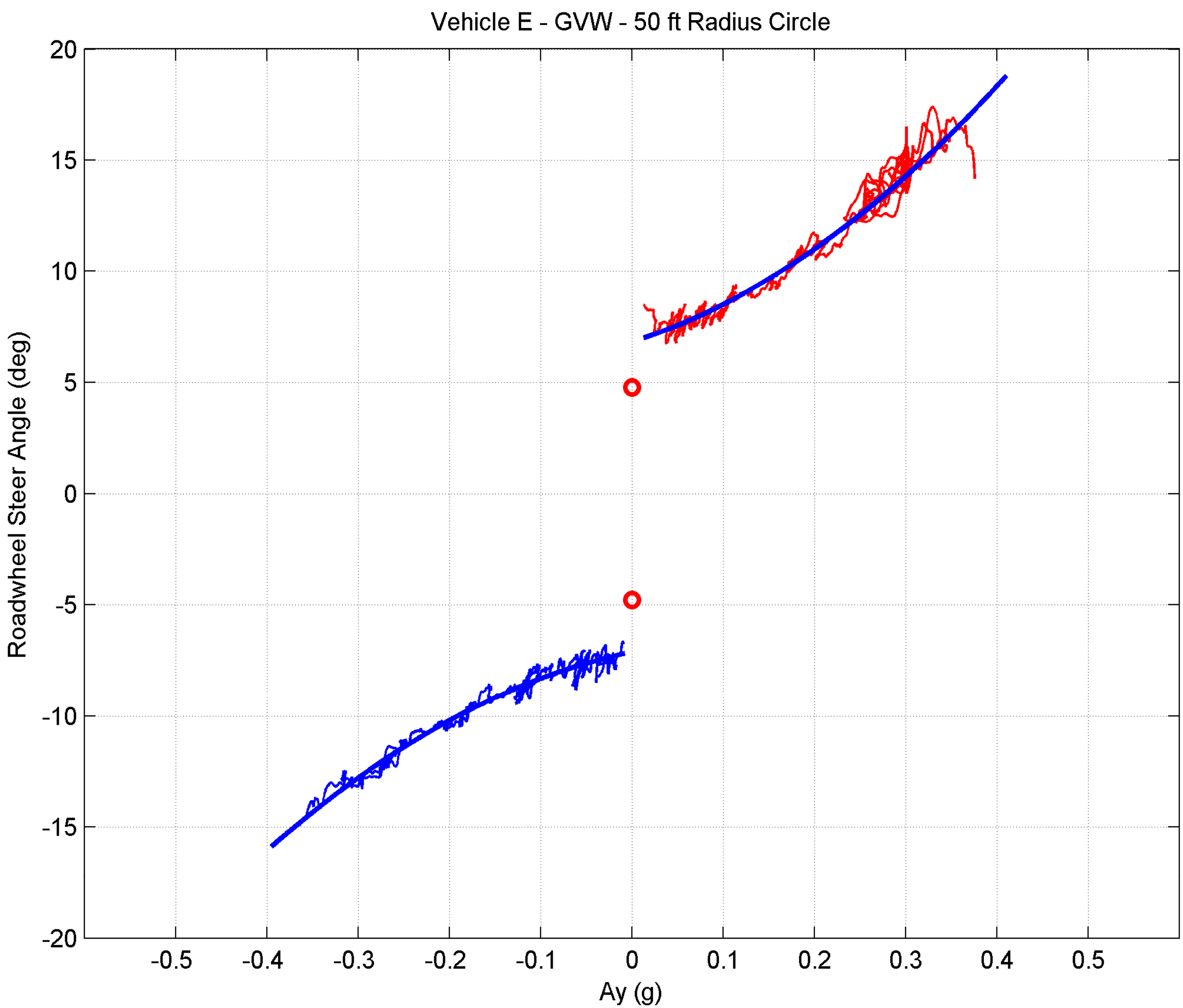
Vehicle D - GVW
15 mph Frequency Response
Ay Mag. (g/deg)
0.06
0.05
0.04
0.03
0.02
0.01
10^0
Roll Angle Mag. (deg/deg)
1
0.8
0.6
0.4
0.2
0
Ay Phase (deg)
0
-50
-100
-150
-200
Frequency (Hz)
Roll Angle Phase (deg)
-250
-300
-350

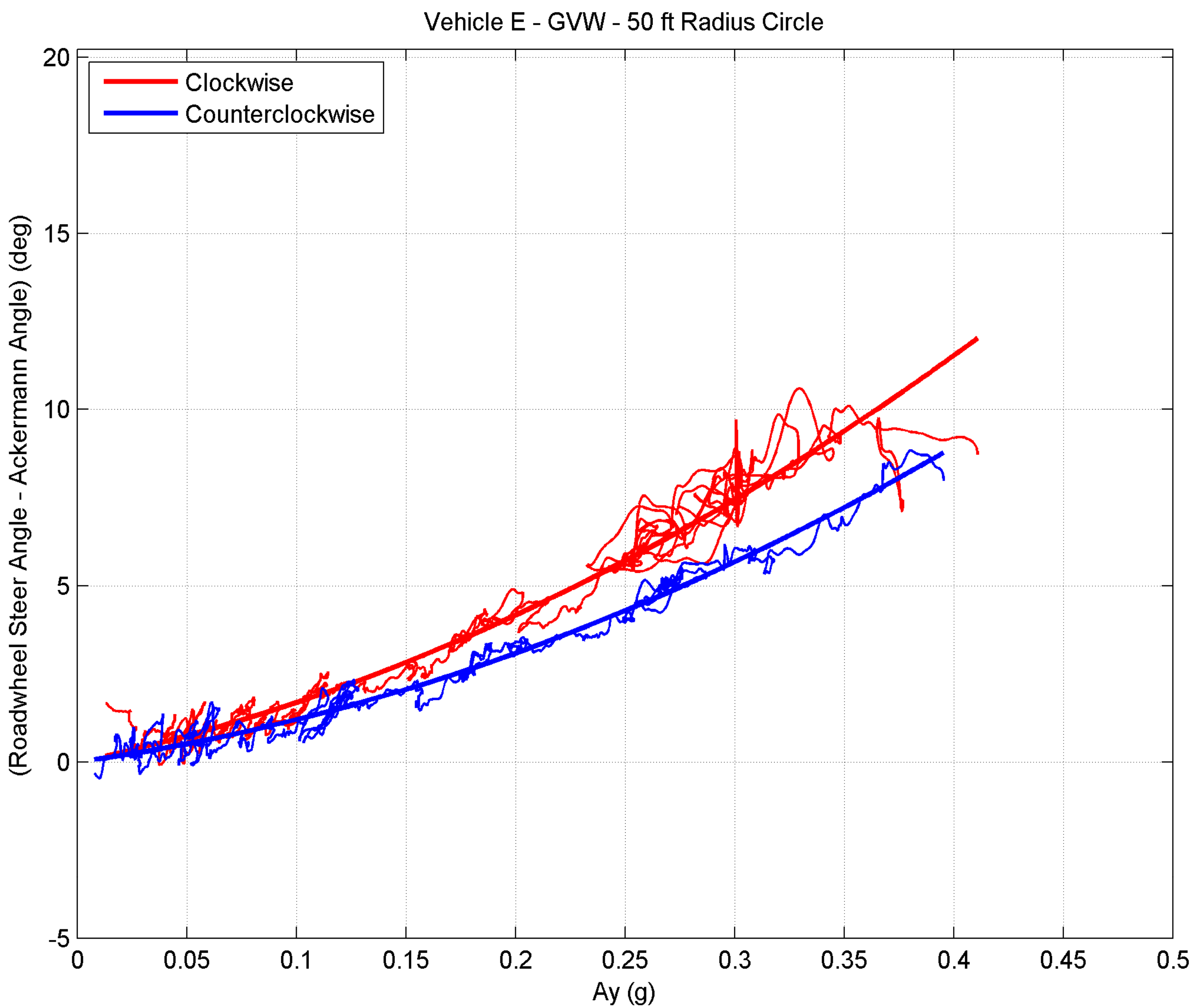


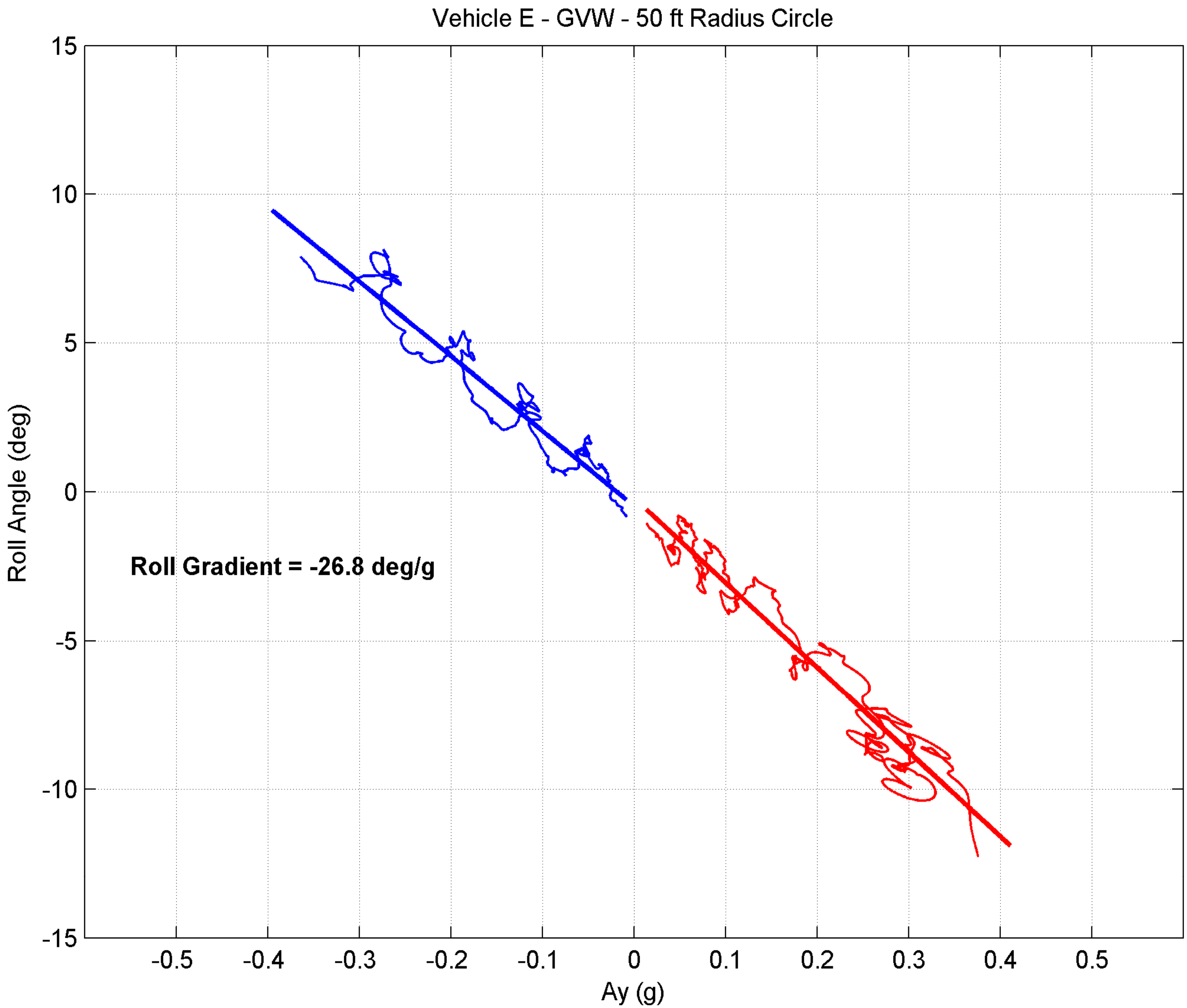
Vehicle D - GVW
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)

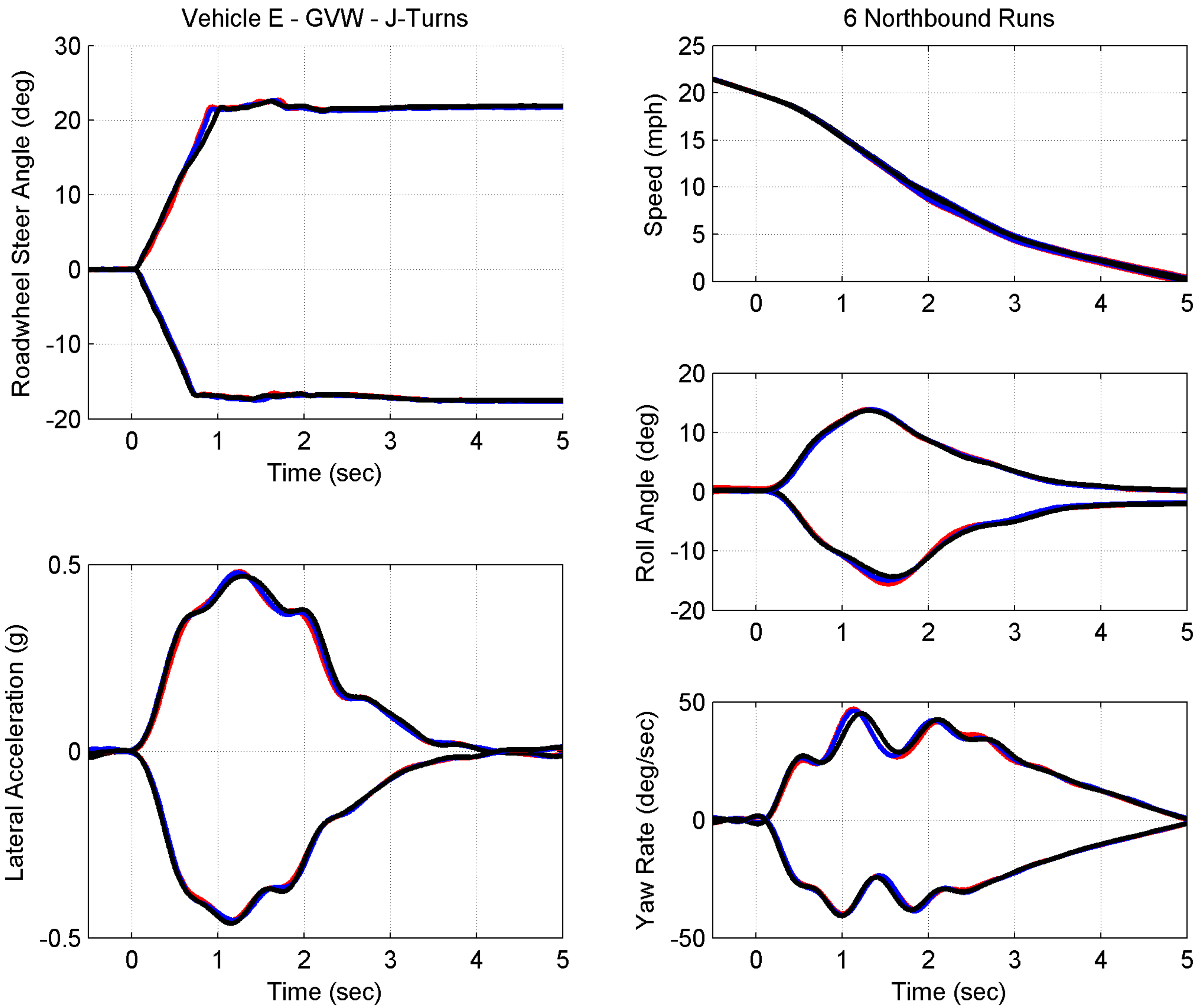


Vehicle E - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
50
100
150
Speed (mph)
25
20
15
10
5
0
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

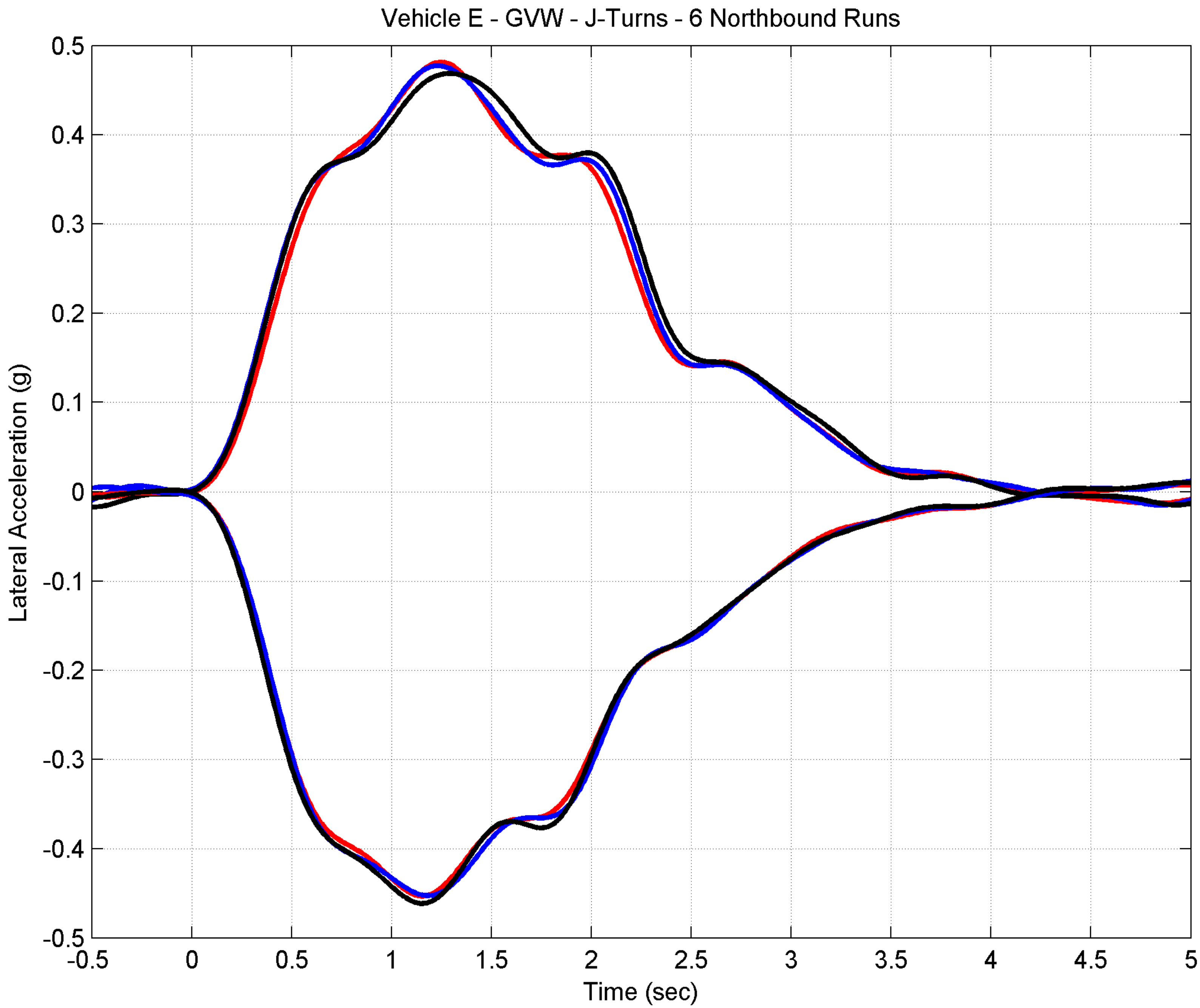

Vehicle E - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
20
15
10
5
0
-5
-10
-15
-20
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

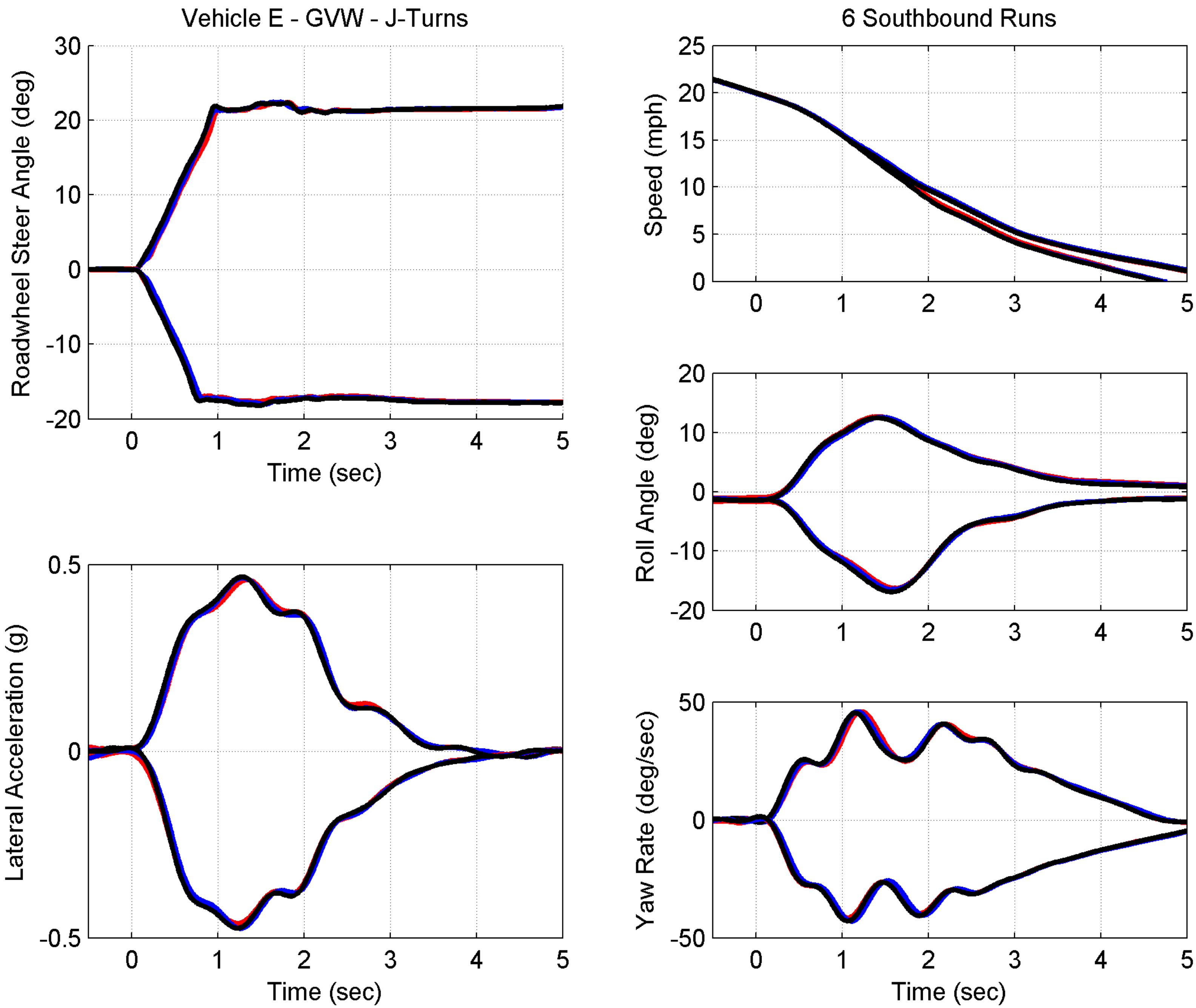

Vehicle E - GVW - 50 ft Radius Circle
Clockwise
Counterclockwise
(Roadwheel Steer Angle - Ackermann Angle) (deg)
20
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Ay (g)


Vehicle E - GVW - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -26.8 deg/g
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

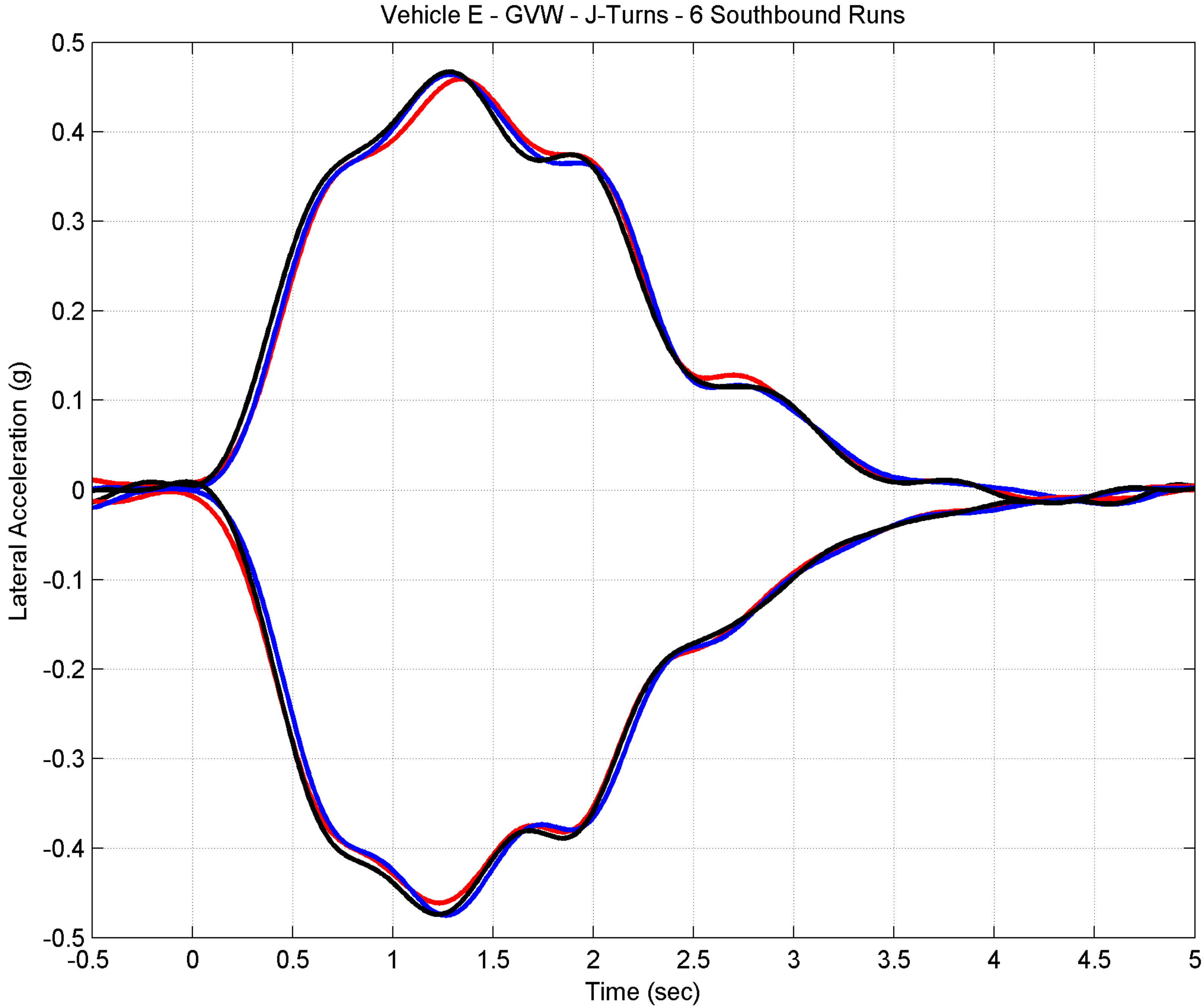


Vehicle E - GVW - J-Turns
6 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle E - GVW - J-Turns - 6 Northbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)



Vehicle E - GVW - J-Turns
6 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



Vehicle E - GVW - J-Turns - 6 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle E - GVW

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

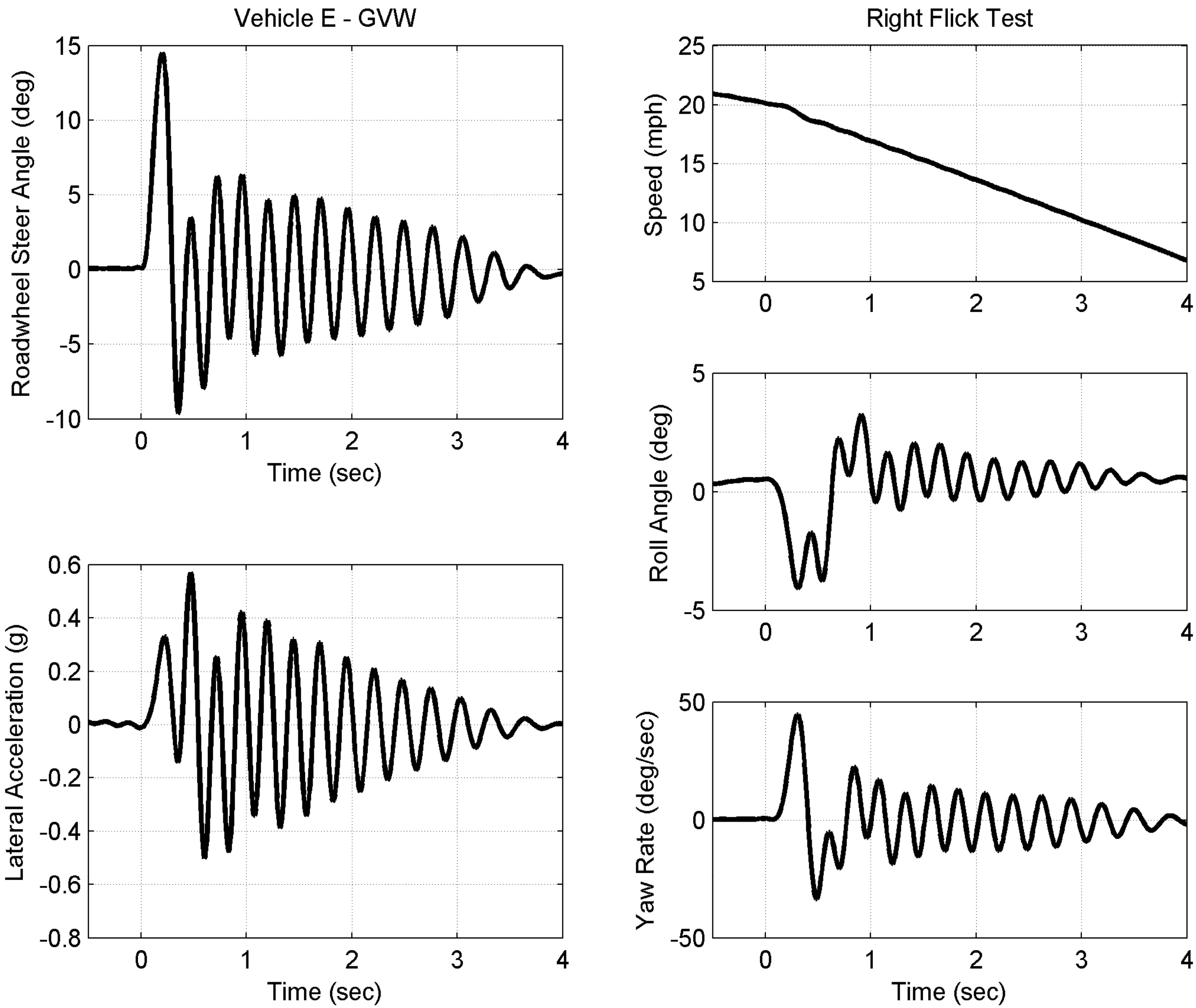
Run Number	Northbound Right Turns	Northbound Left Turns	Average of 6 Northbound Runs
1	0.4815	-0.4535	
2	0.4774	-0.4529	
3	0.4687	-0.4617	
Mean Value of 3 Runs	0.4759	-0.4560	**0.4659**
Standard Deviation of 3 Runs	0.007	0.005	

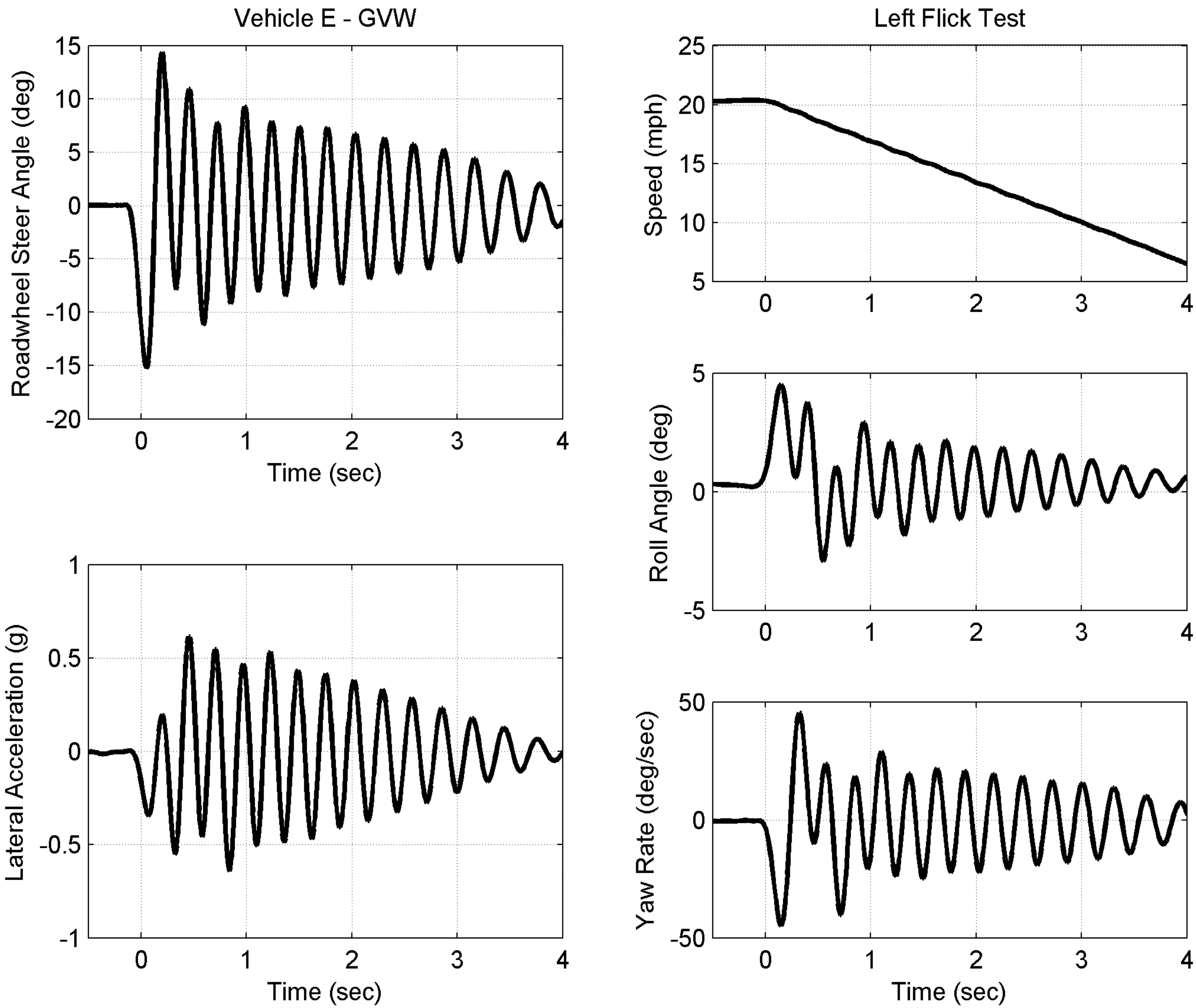
Run Number	Southbound Right Turns	Southbound Left Turns	Average of 6 Southbound Runs
1	0.4590	-0.4615	
2	0.4642	-0.4752	
3	0.4671	-0.4744	
Mean Value of 3 Runs	0.4634	-0.4704	**0.4669**
Standard Deviation of 3 Runs	0.004	0.008	

Average of All 12 Runs

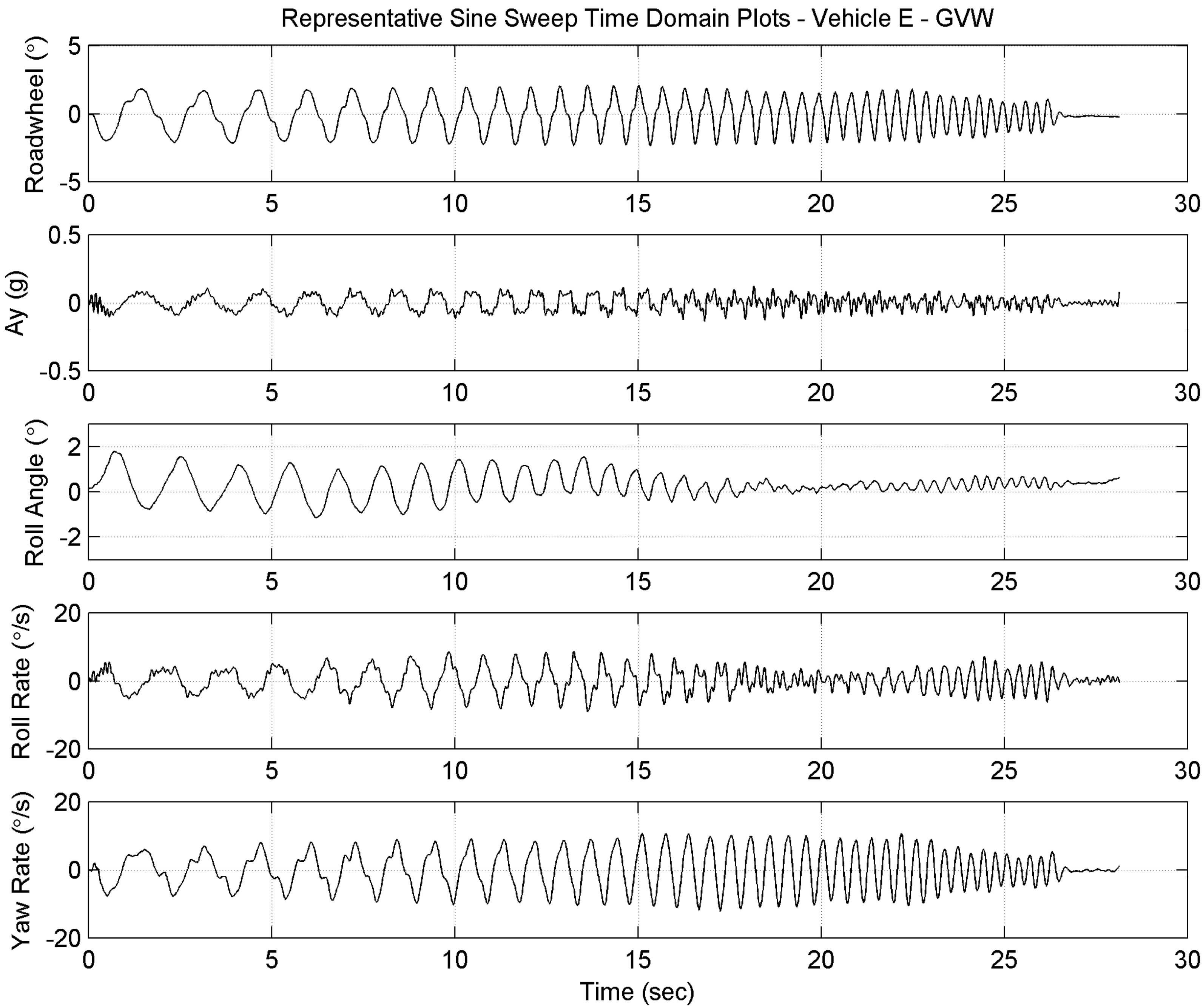
0.466

Threshold Ay

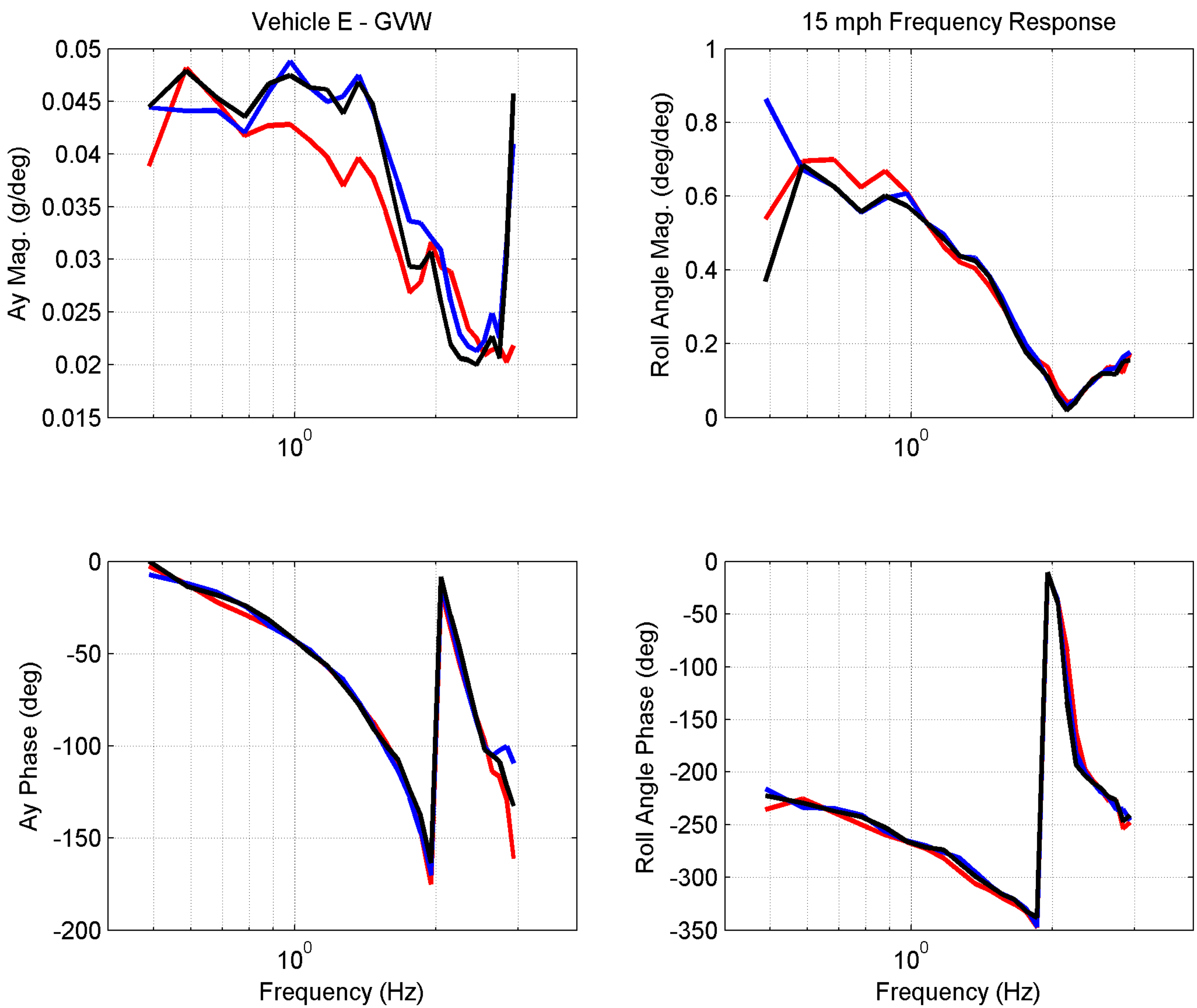

Vehicle E - GVW
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

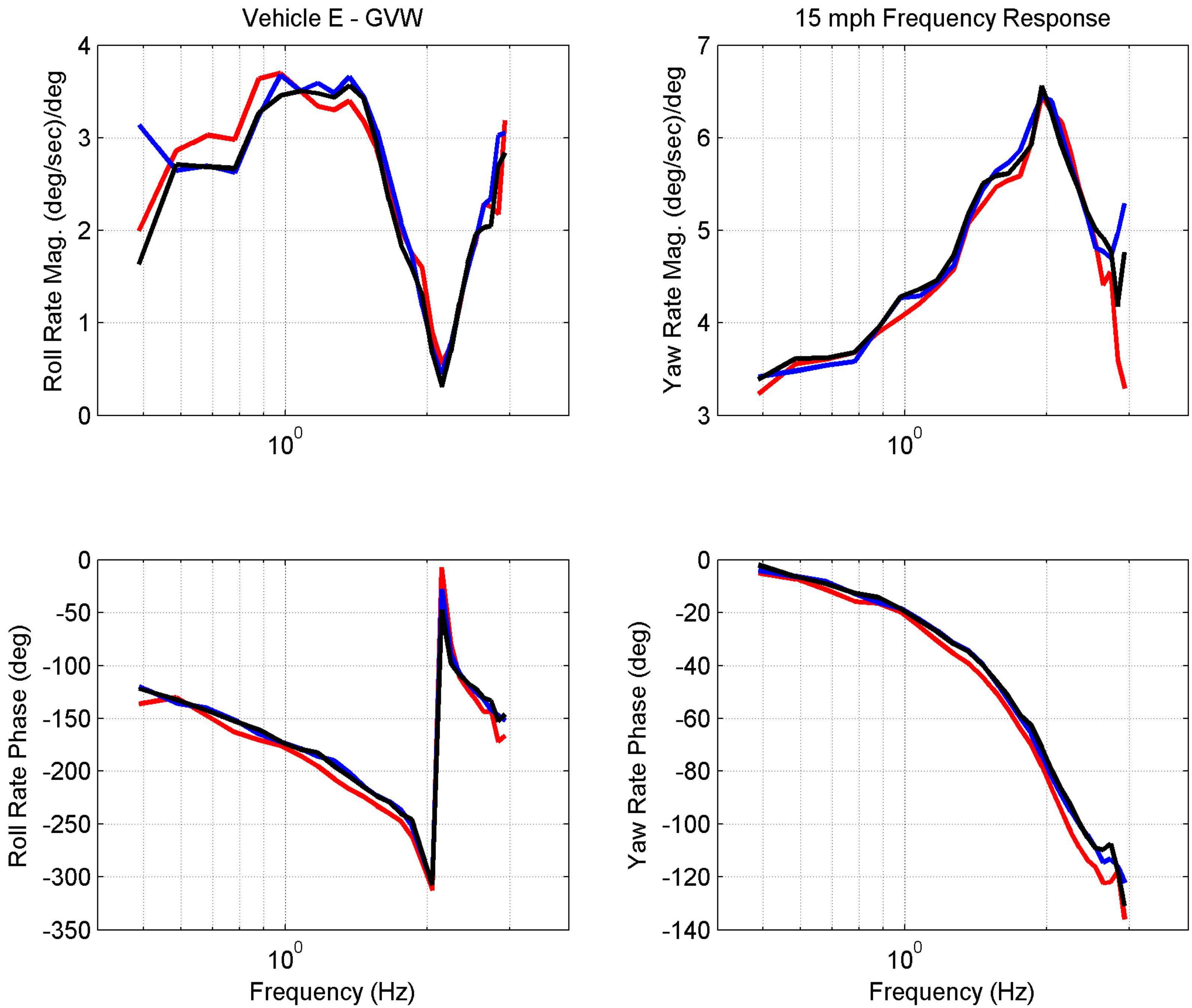


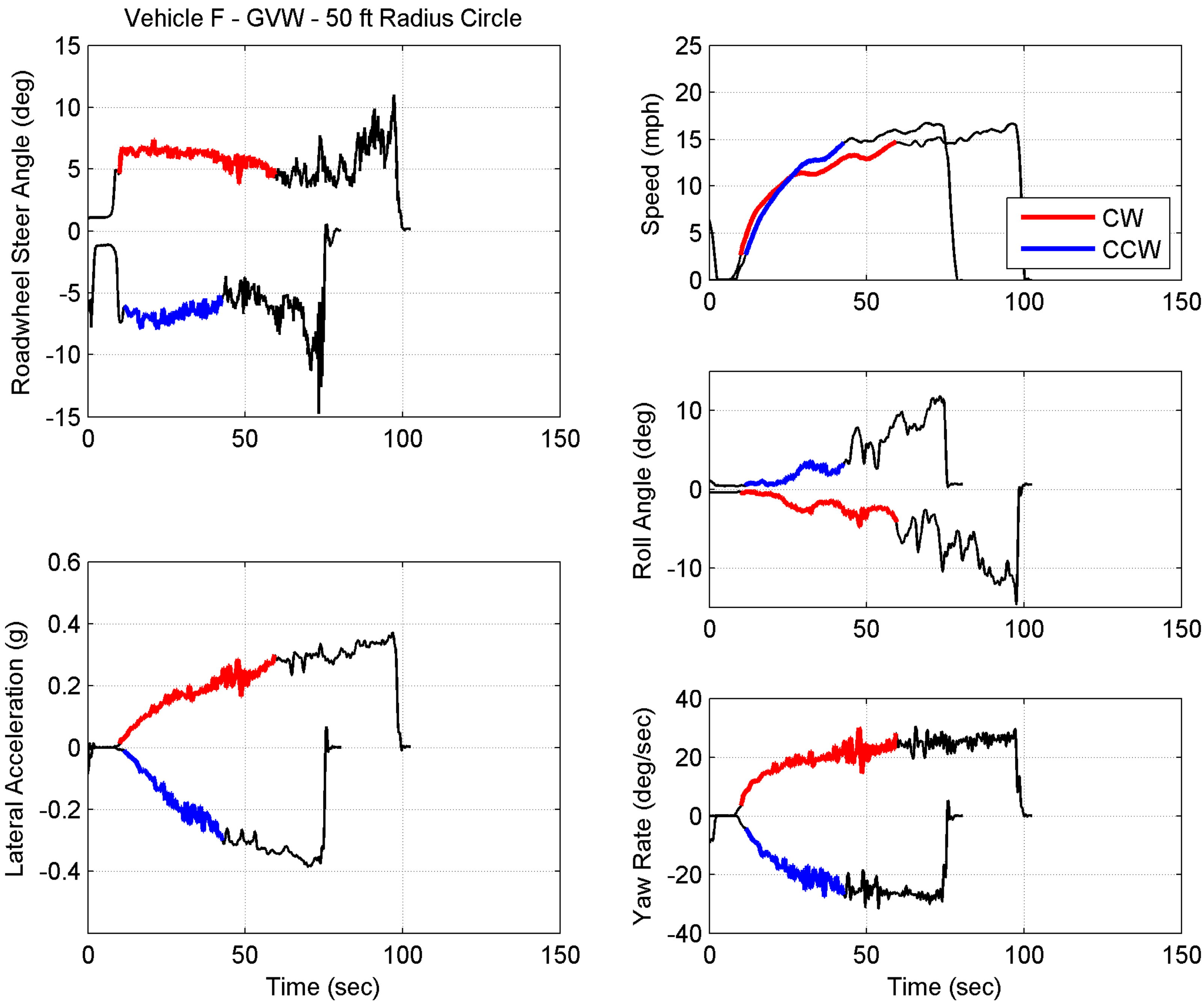
Vehicle E - GVW
Left Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



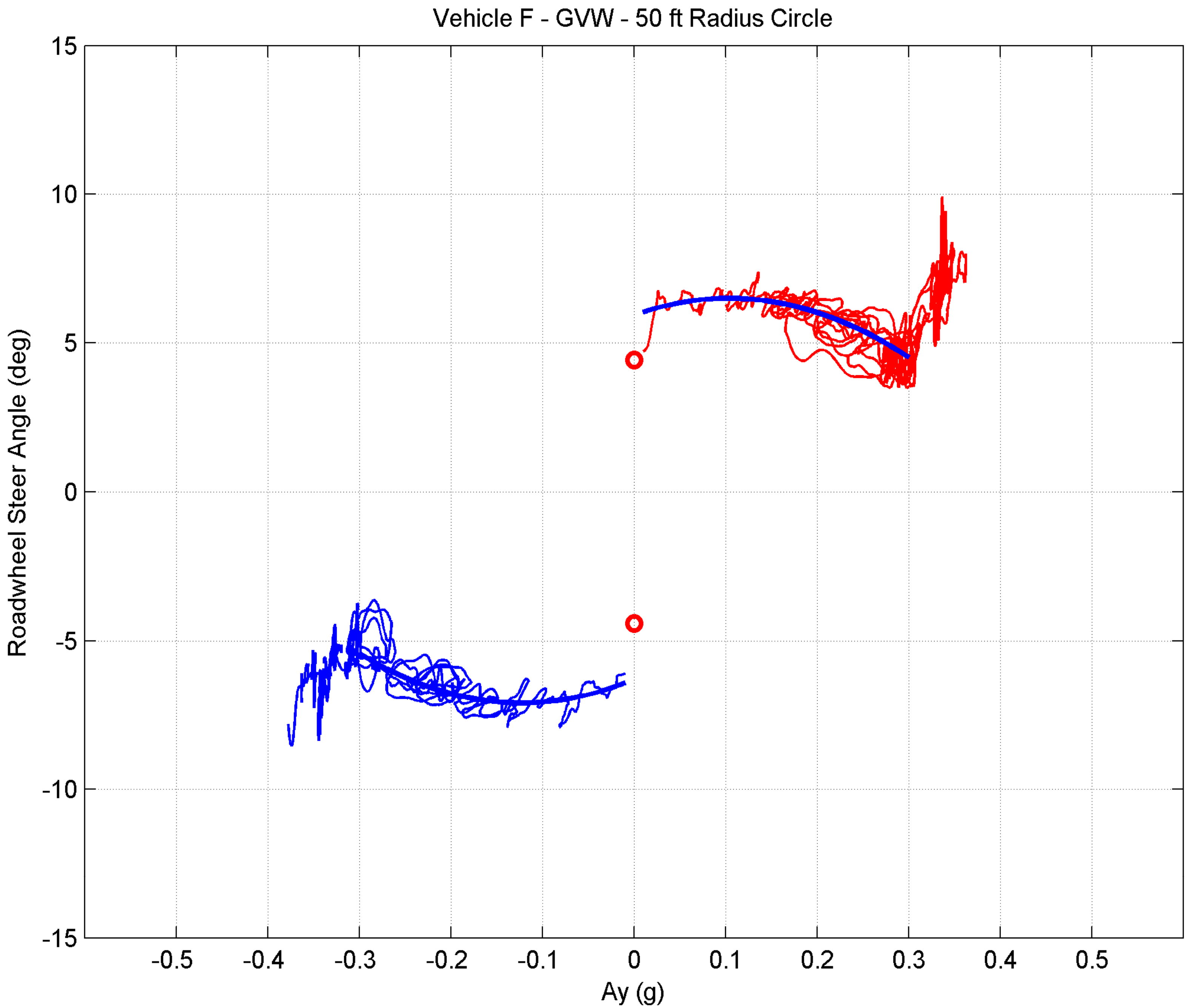
Representative Sine Sweep Time Domain Plots - Vehicle E - GVW
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)


Vehicle E - GVW
15 mph Frequency Response
Ay Mag. (g/deg)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
Roll Angle Mag. (deg/deg)
1
0.8
0.6
0.4
0.2
0
Ay Phase (deg)
0
-50
-100
-150
-200
Roll Angle Phase (deg)
0
-50
-100
-150
-200
-250
-300
-350
10^0
Frequency (Hz)

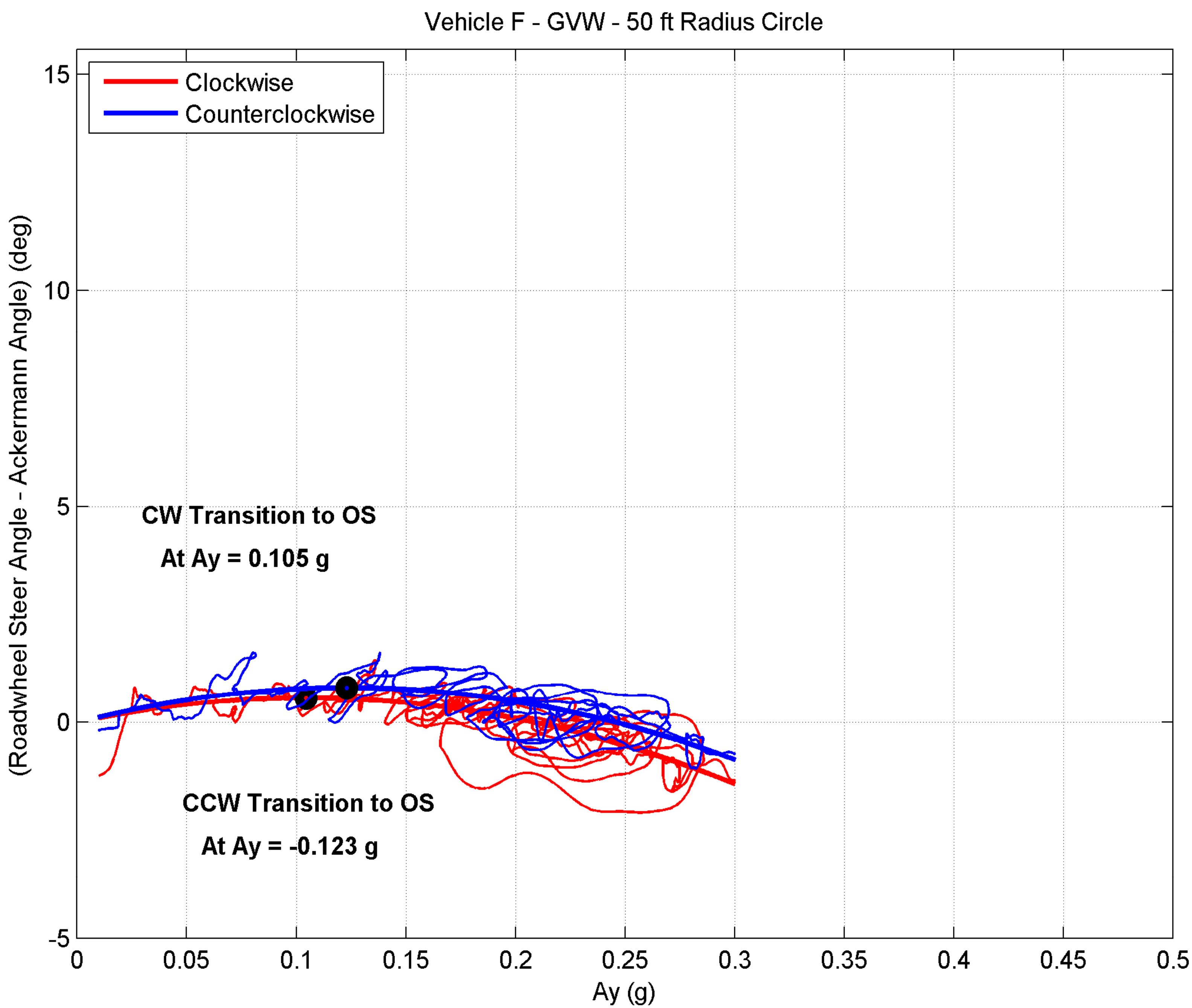

Vehicle E - GVW
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
4
3
2
1
0
7
6
5
4
3
0
-50
-100
-150
-200
-250
-300
-350
0
-20
-40
-60
-80
-100
-120
-140
10^0
10^0
10^0
10^0

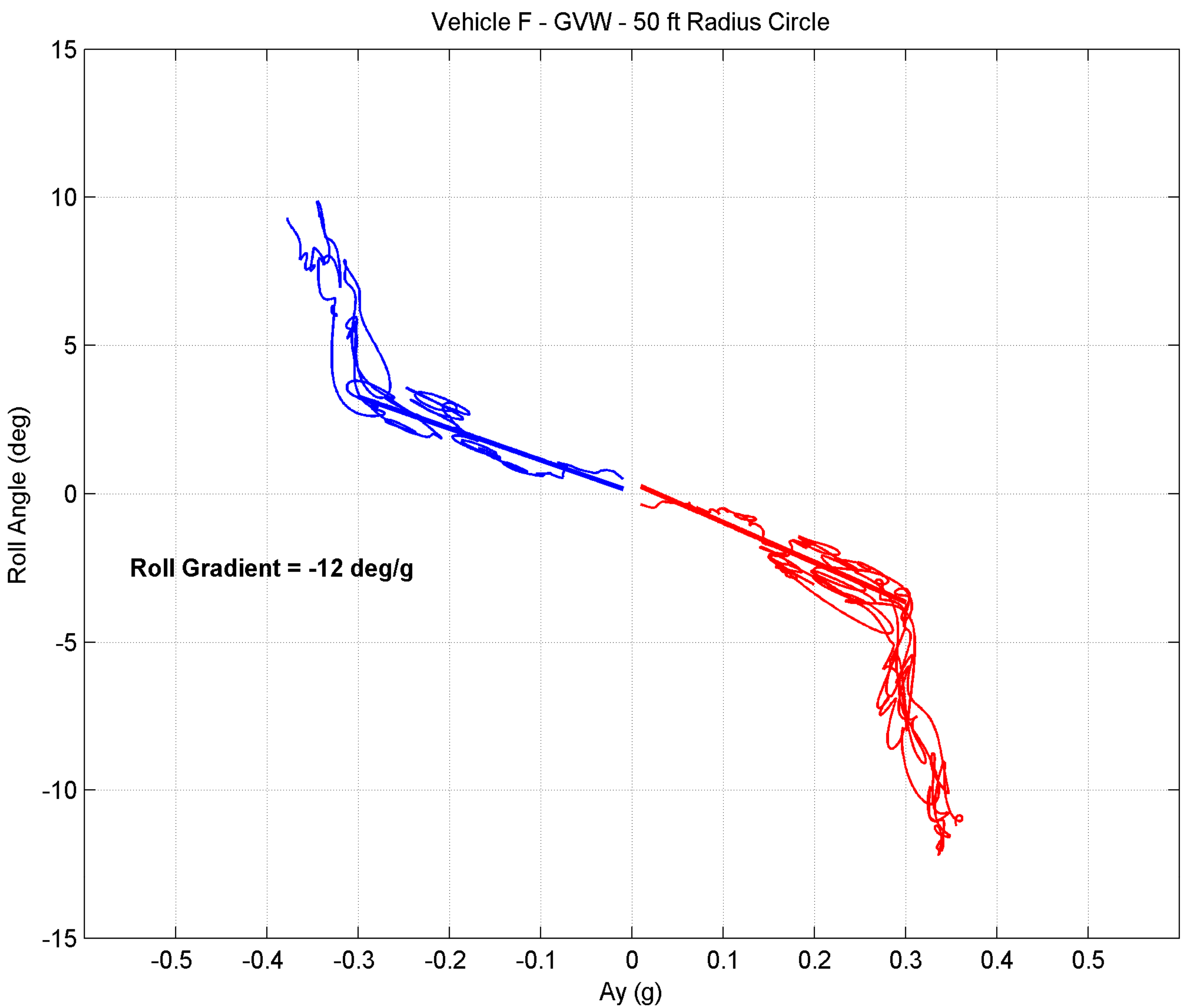


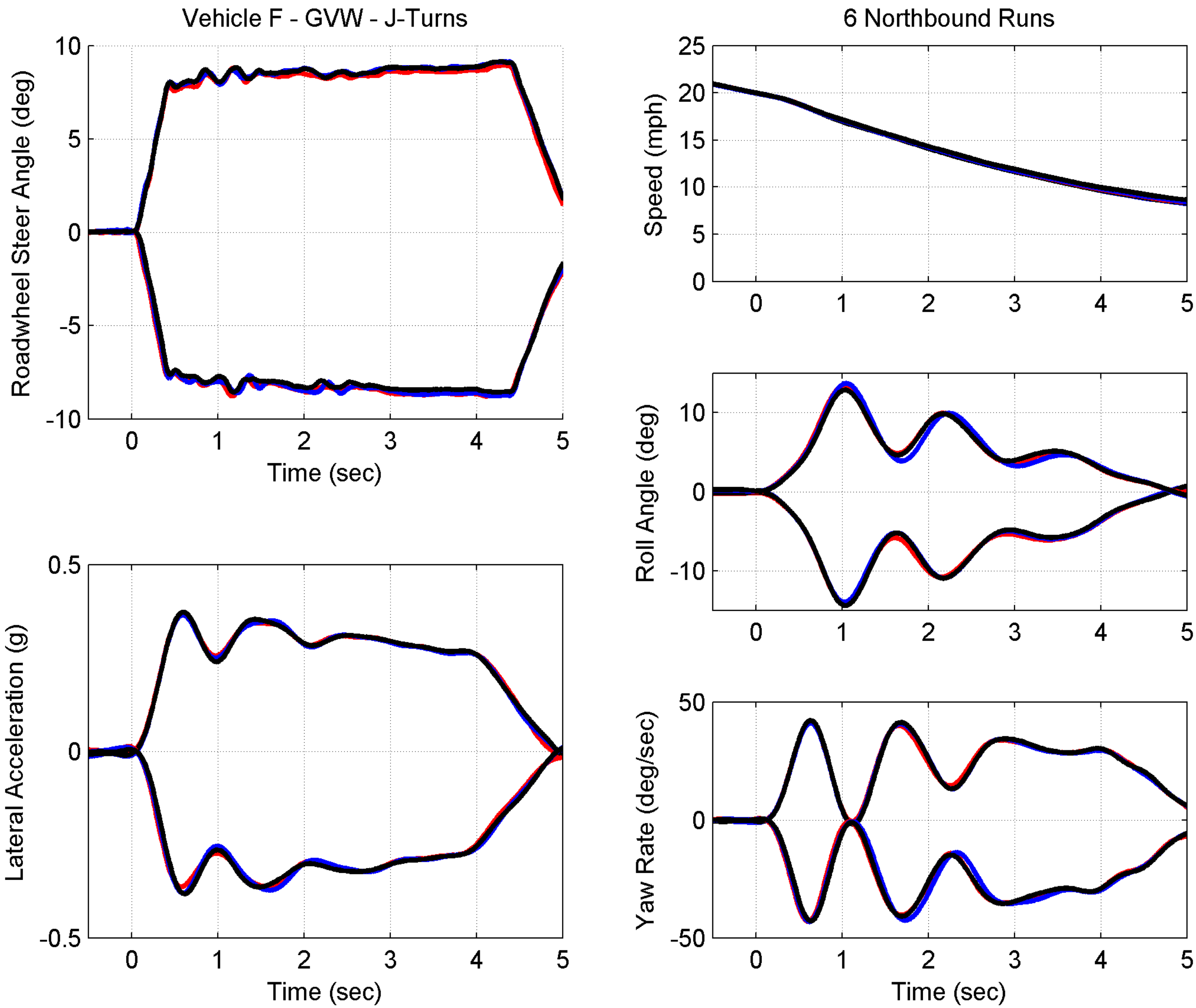
Vehicle F - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



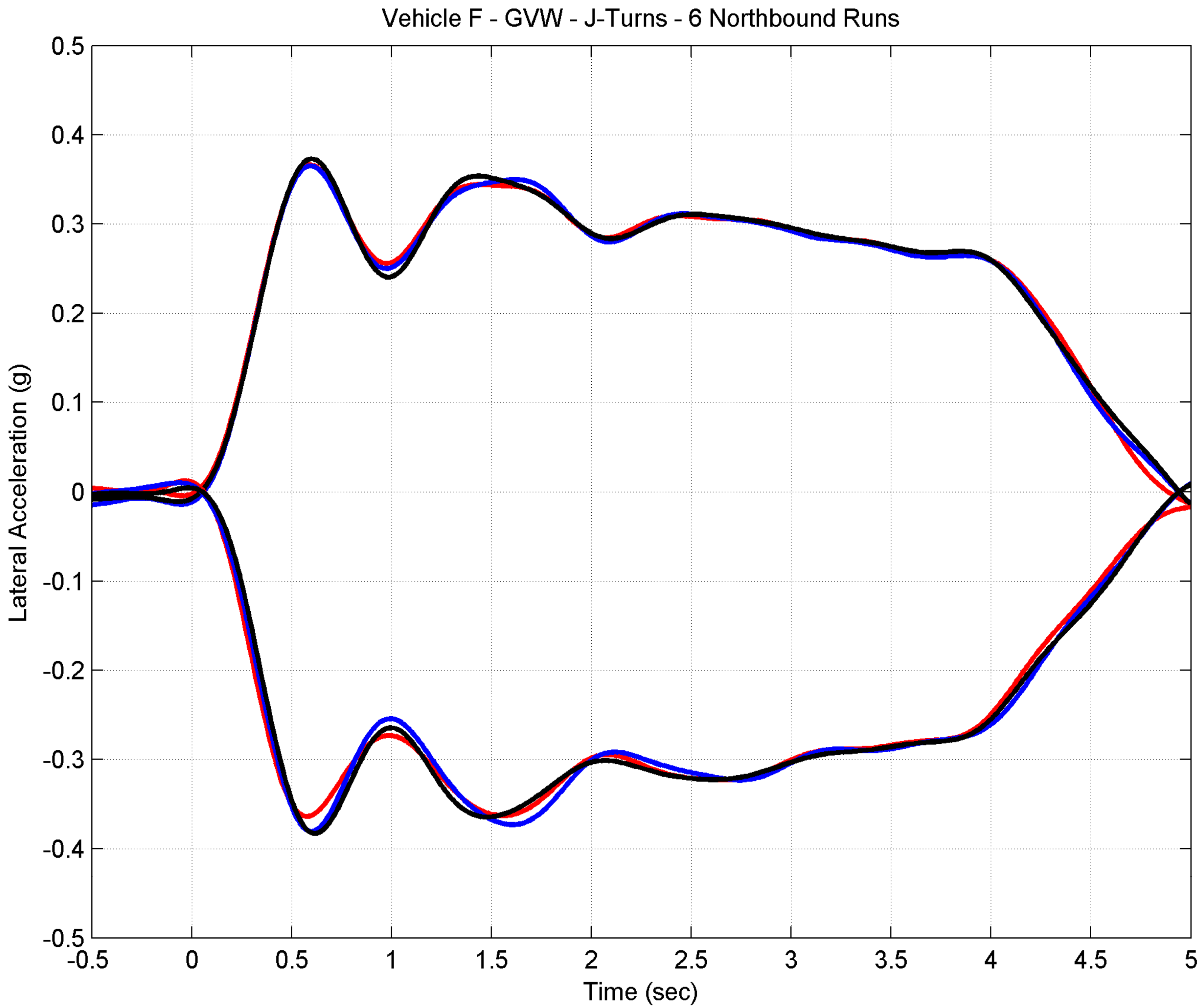
Vehicle F - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

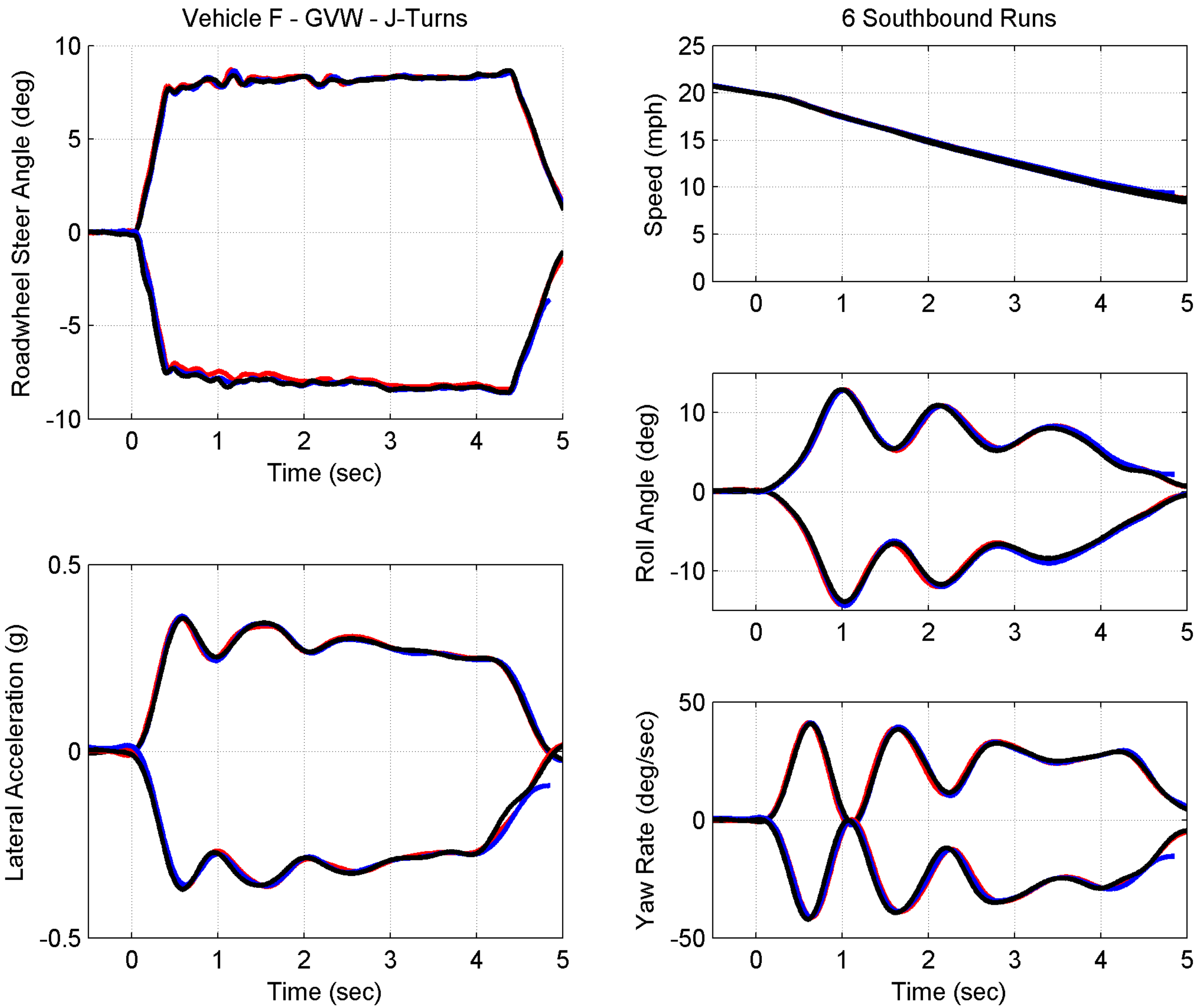

Vehicle F - GVW - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.105 g
CCW Transition to OS
At Ay = -0.123 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

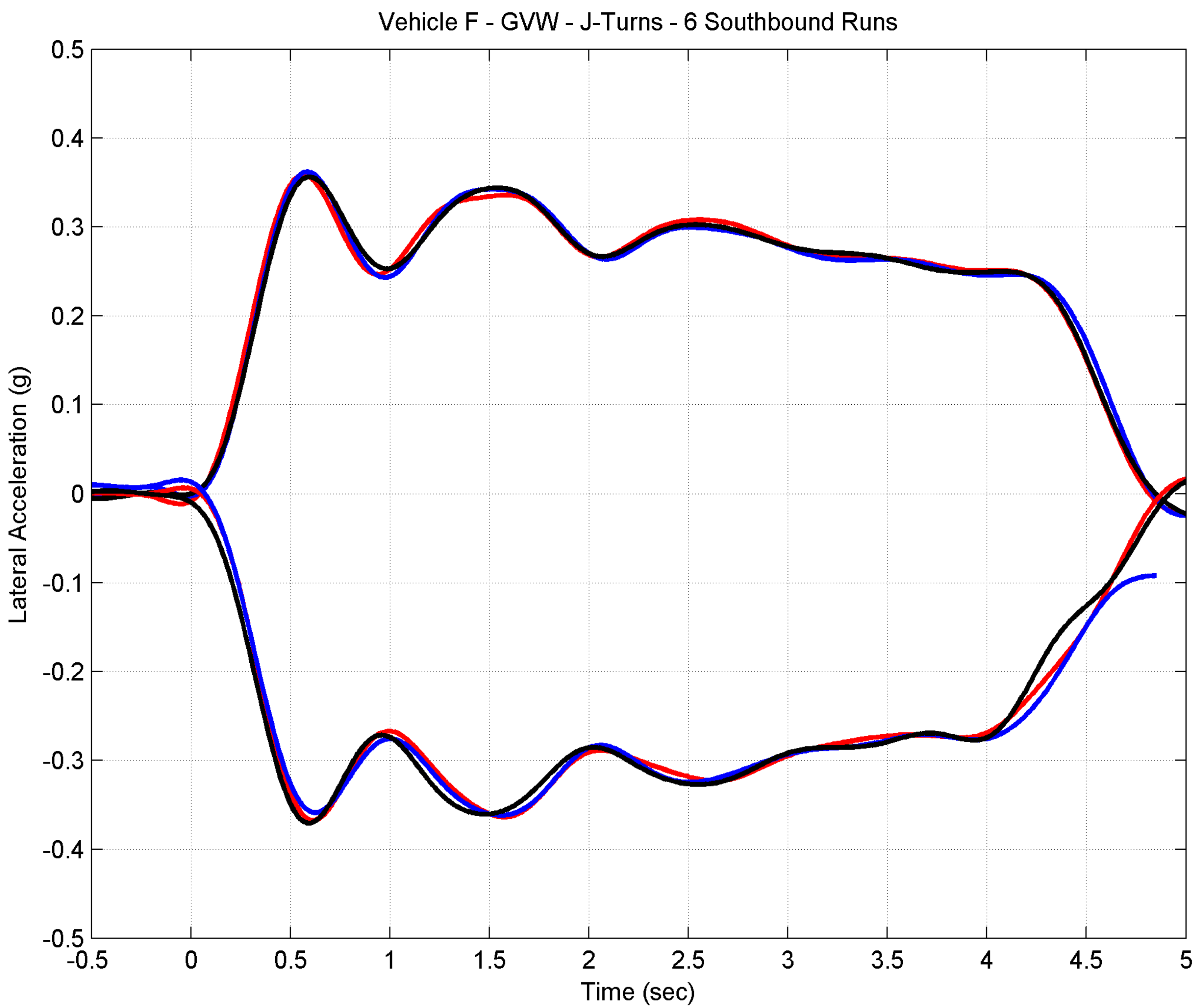

Vehicle F - GVW - 50 ft Radius Circle
15
10
5
0
-5
-10
-15
Roll Angle (deg)
Roll Gradient = -12 deg/g
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)



Vehicle F - GVW - J-Turns
6 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)


Vehicle F - GVW - J-Turns - 6 Northbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle F - GVW - J-Turns
6 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)


Vehicle F - GVW - J-Turns - 6 Southbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle F - GVW

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.3658	-0.3639
2	0.3649	-0.3807
3	0.3728	-0.3830
Mean Value of 3 Runs	0.3678	-0.3759
Standard Deviation of 3 Runs	0.004	0.010

Average of 6 Northbound Runs

0.3719

Run Number	Southbound Right Turns	Southbound Left Turns
1	0.3582	-0.3675
2	0.3618	-0.3617
3	0.3559	-0.3706
Mean Value of 3 Runs	0.3587	-0.3666
Standard Deviation of 3 Runs	0.003	0.005

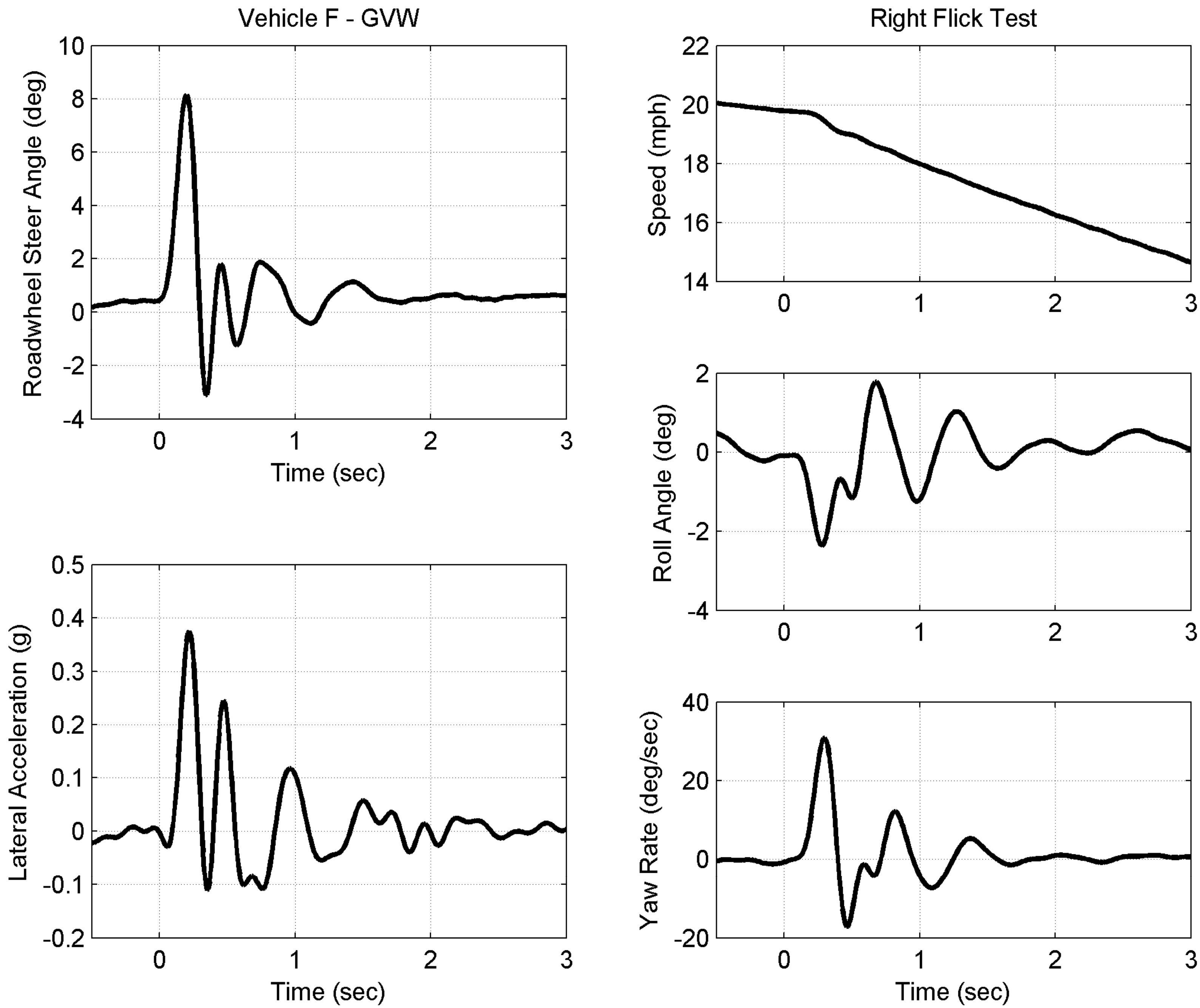
Average of 6 Southbound Runs

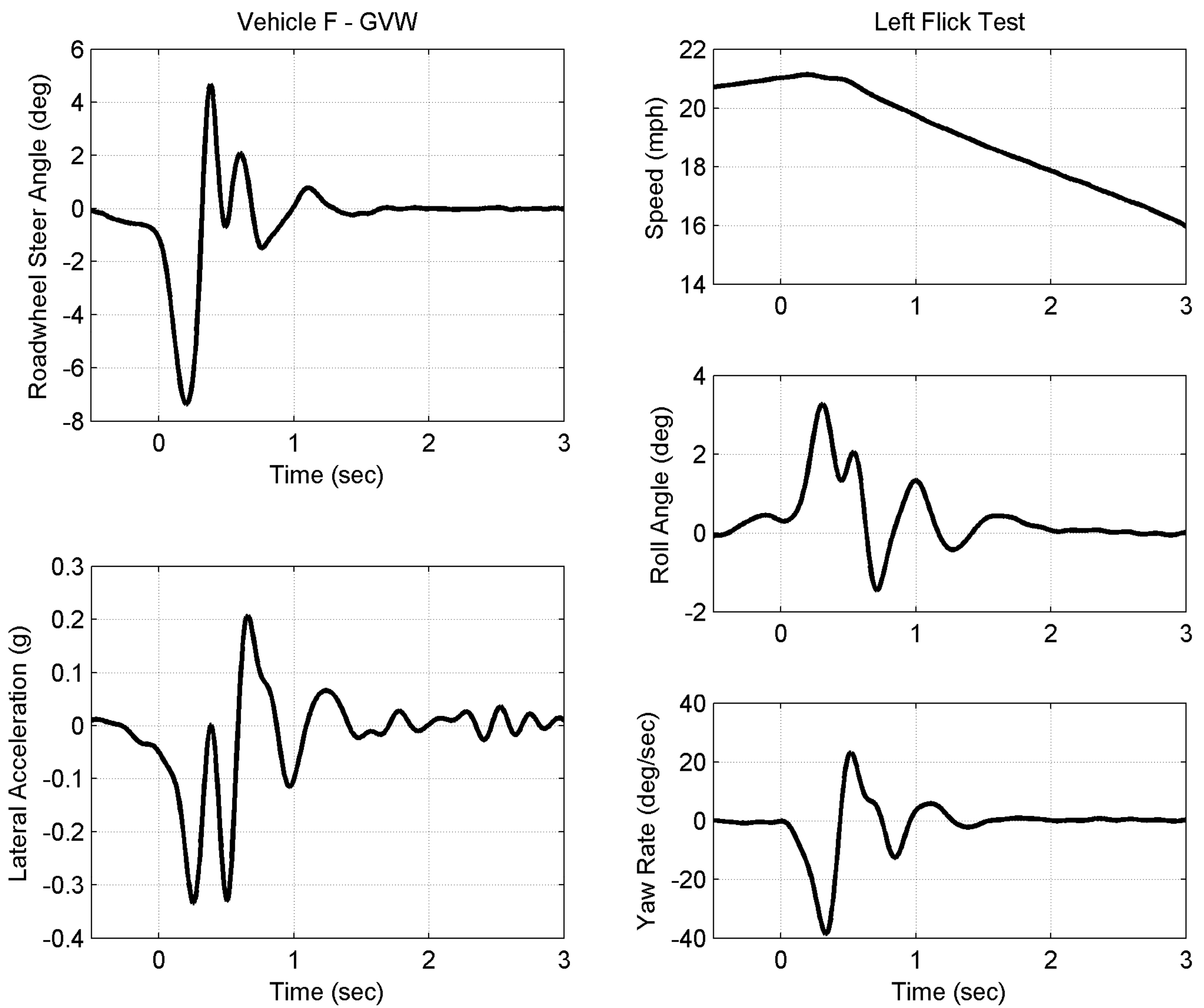
0.3626

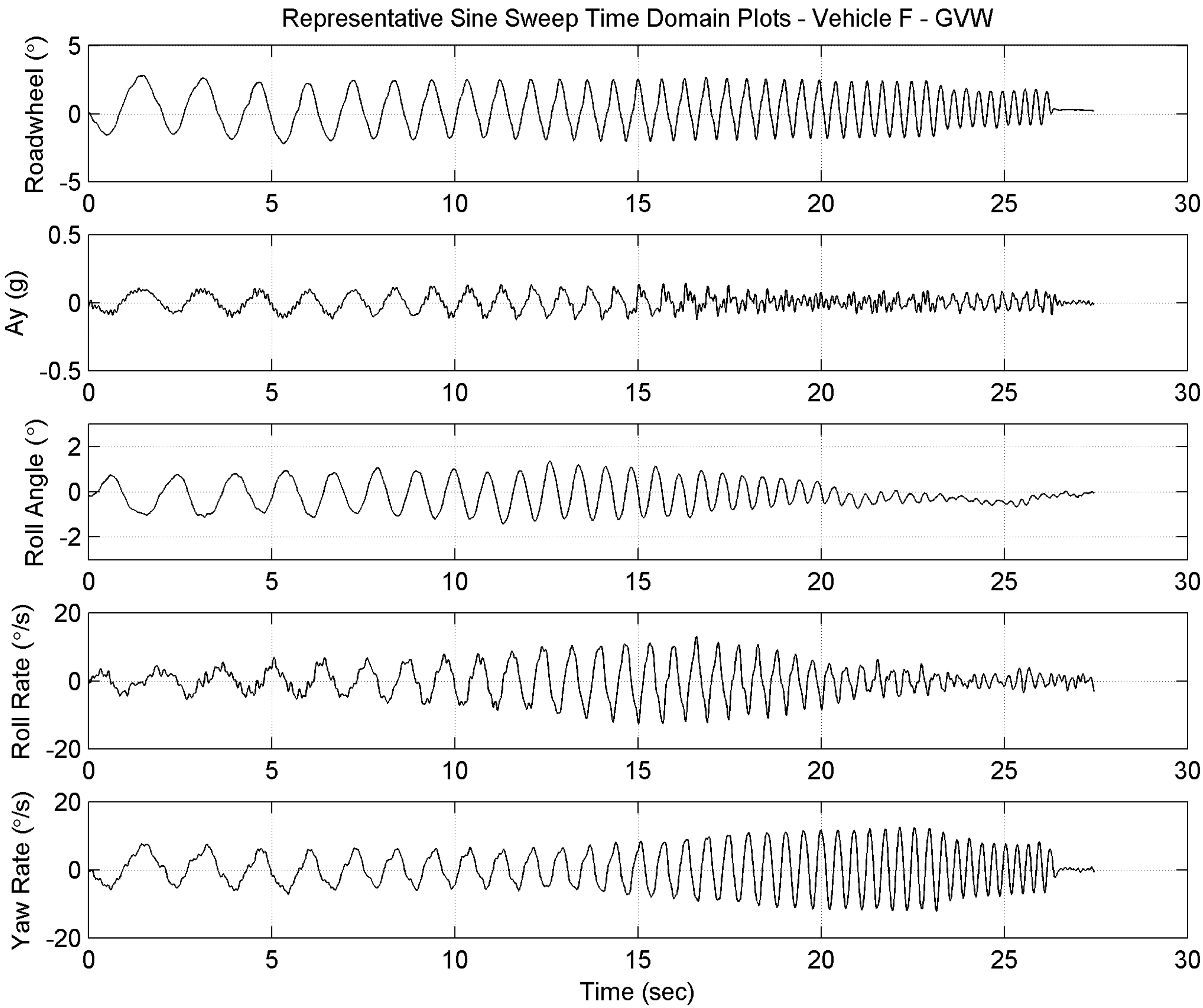
Average of All 12 Runs

0.367

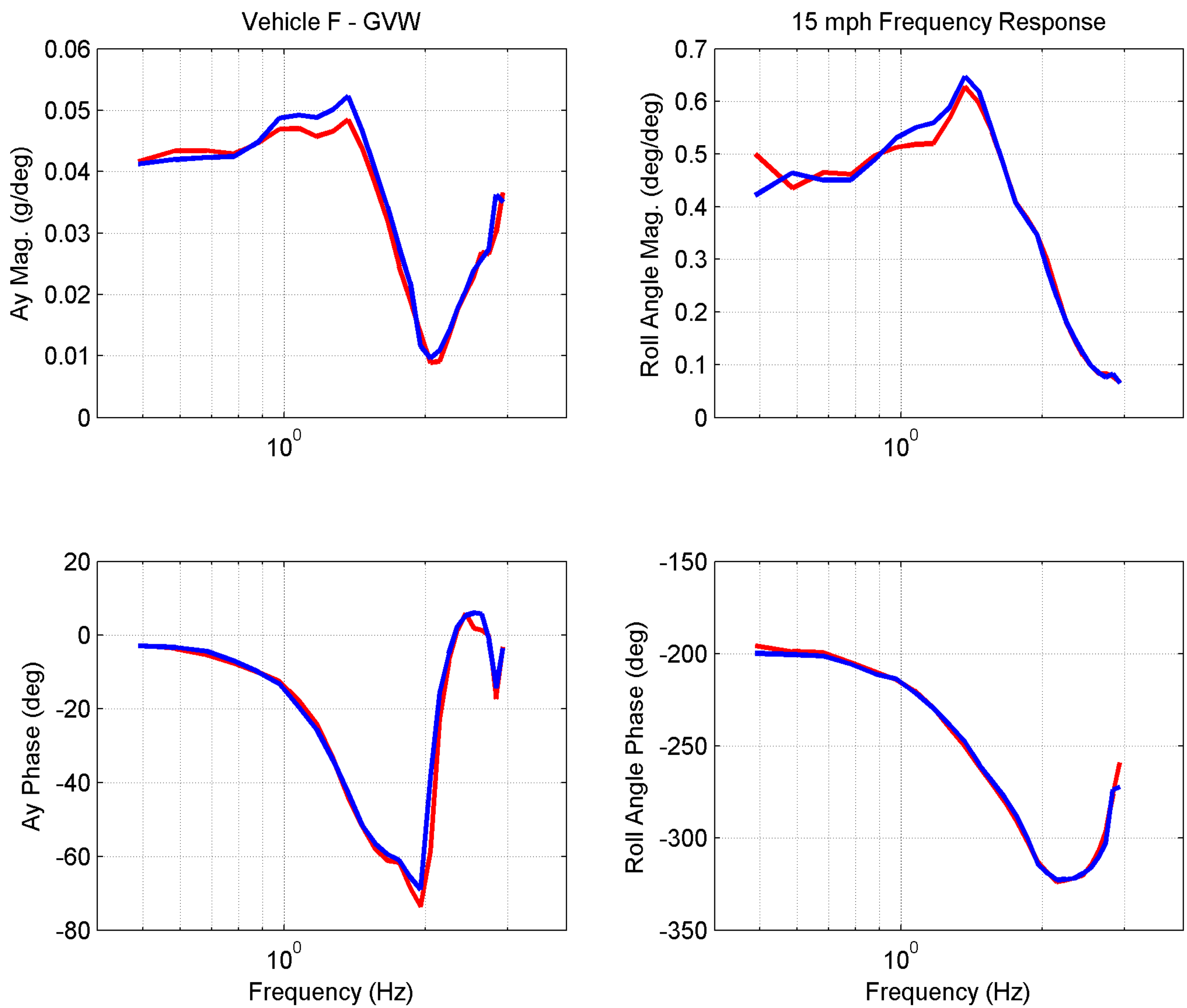
Threshold Ay


Vehicle F - GVW
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

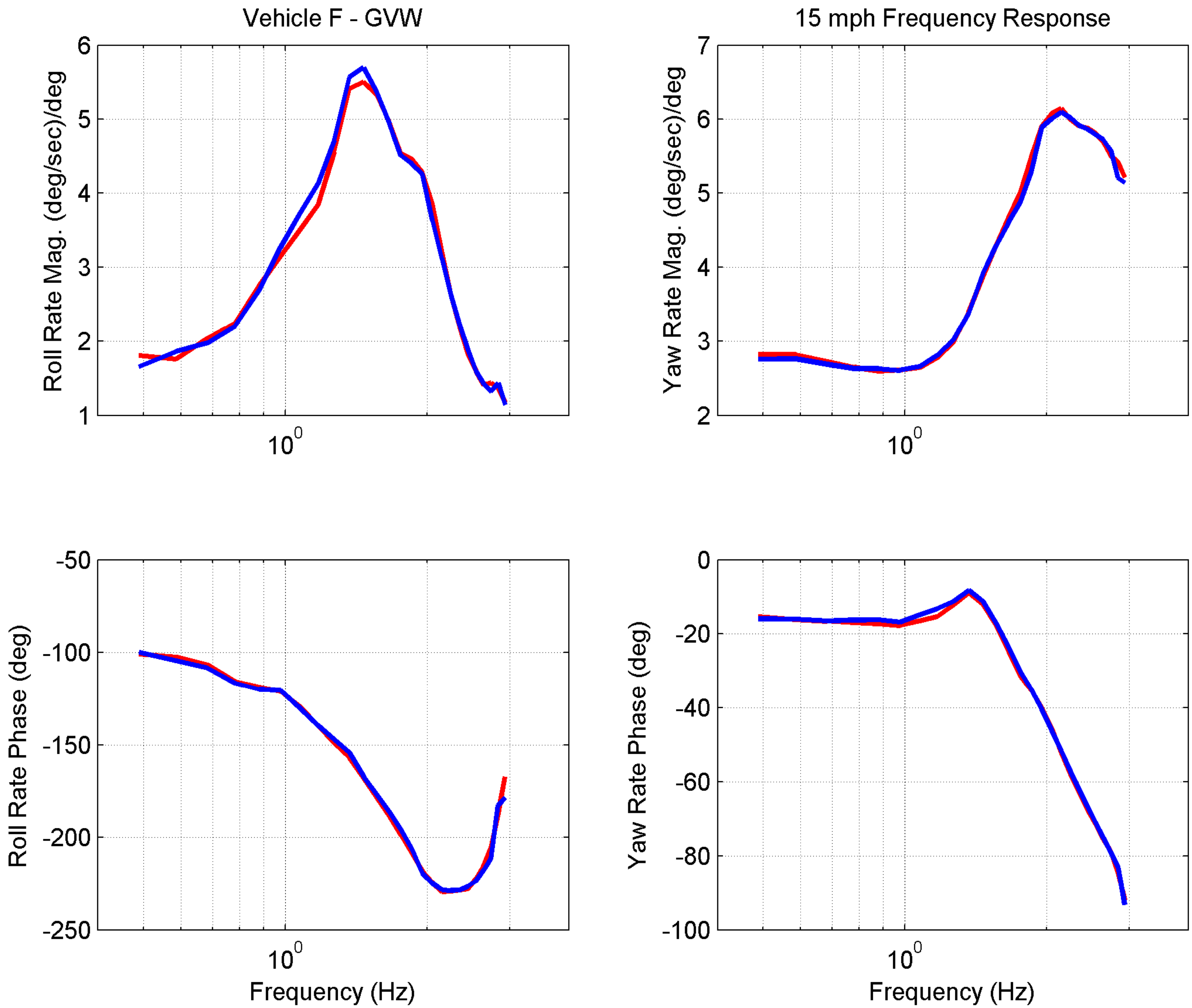

Vehicle F - GVW
Left Flick Test
Roadwheel Steer Angle (deg)
6
4
2
0
-2
-4
-6
-8
0
1
2
3
Time (sec)
Speed (mph)
22
20
18
16
14
Roll Angle (deg)
4
2
0
-2
Lateral Acceleration (g)
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)



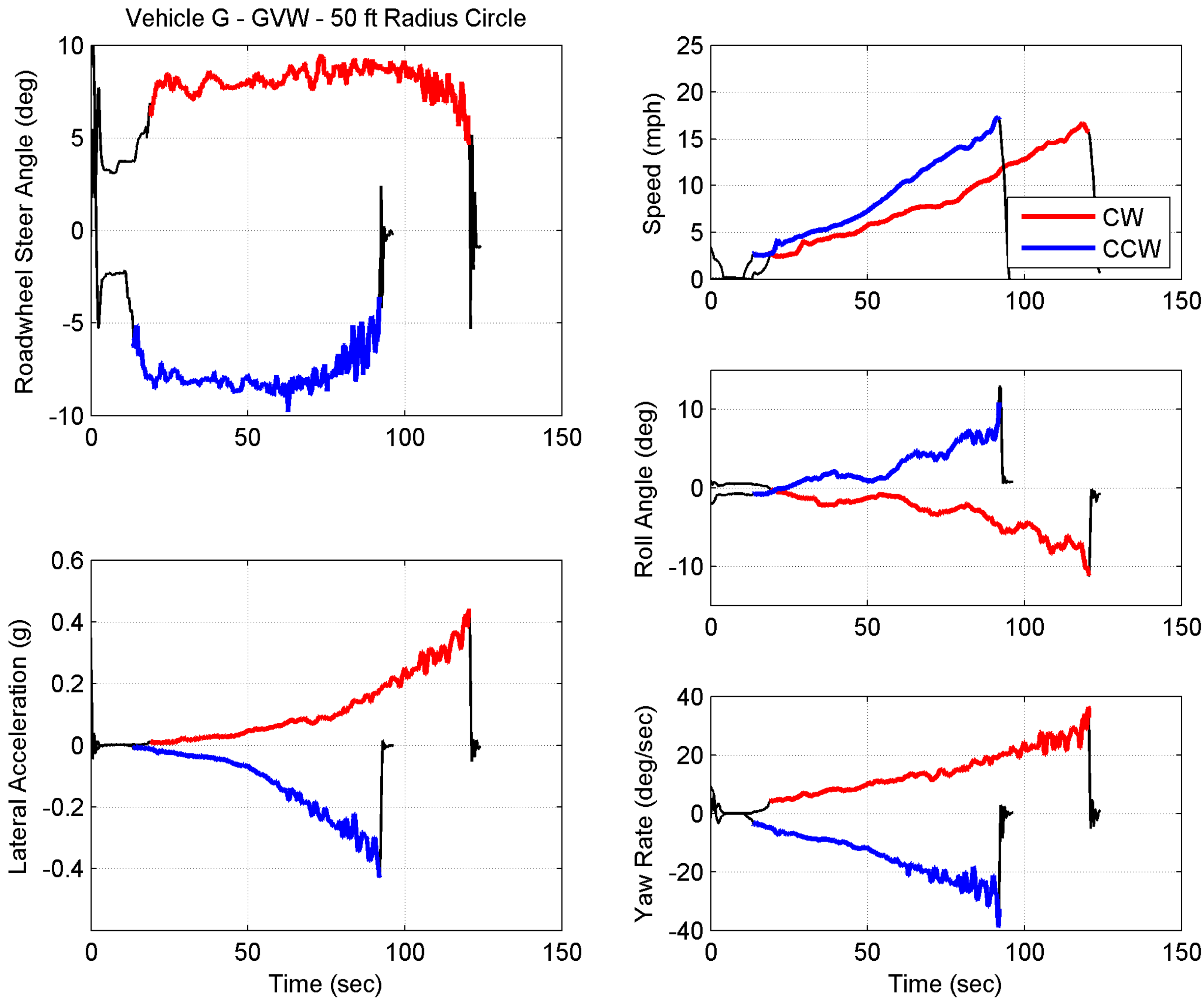
Representative Sine Sweep Time Domain Plots - Vehicle F - GVW
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)



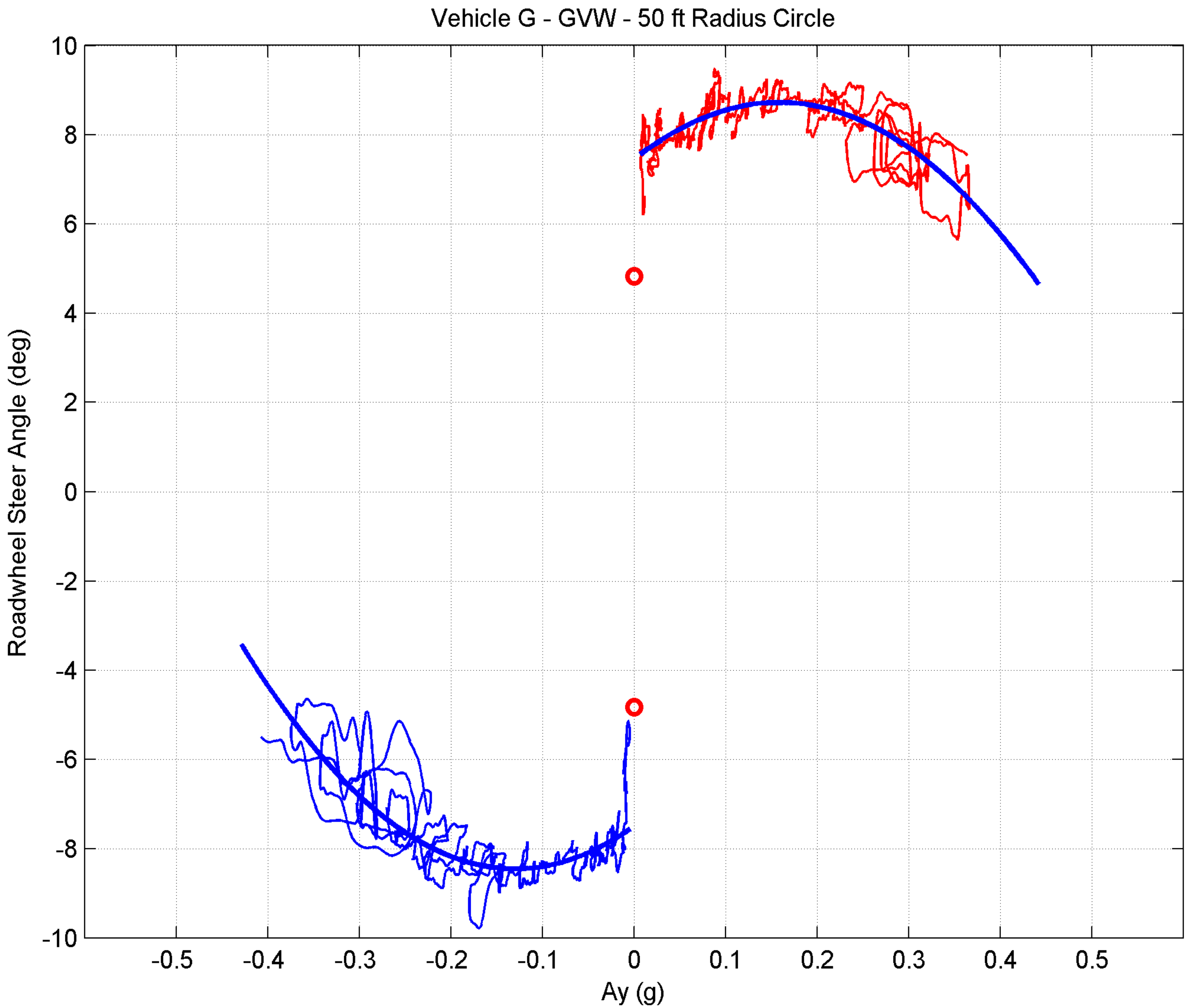
Vehicle F - GVW
15 mph Frequency Response
0.06
0.05
0.04
0.03
0.02
0.01
0
Ay Mag. (g/deg)
10^0
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Roll Angle Mag. (deg/deg)
10^0
20
0
-20
-40
-60
-80
Ay Phase (deg)
10^0
Frequency (Hz)
-150
-200
-250
-300
-350
Roll Angle Phase (deg)
10^0
Frequency (Hz)

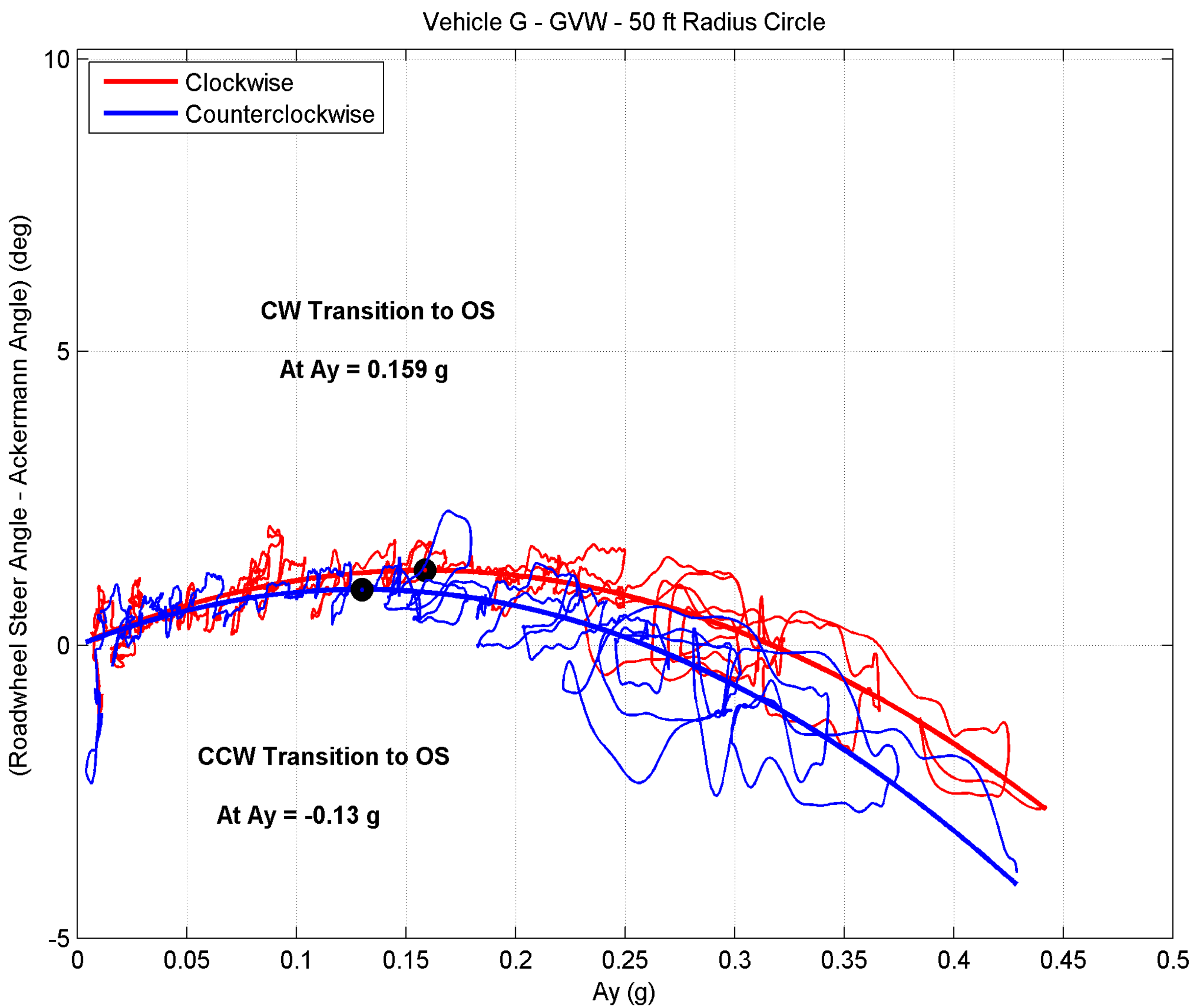


Vehicle F - GVW
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)

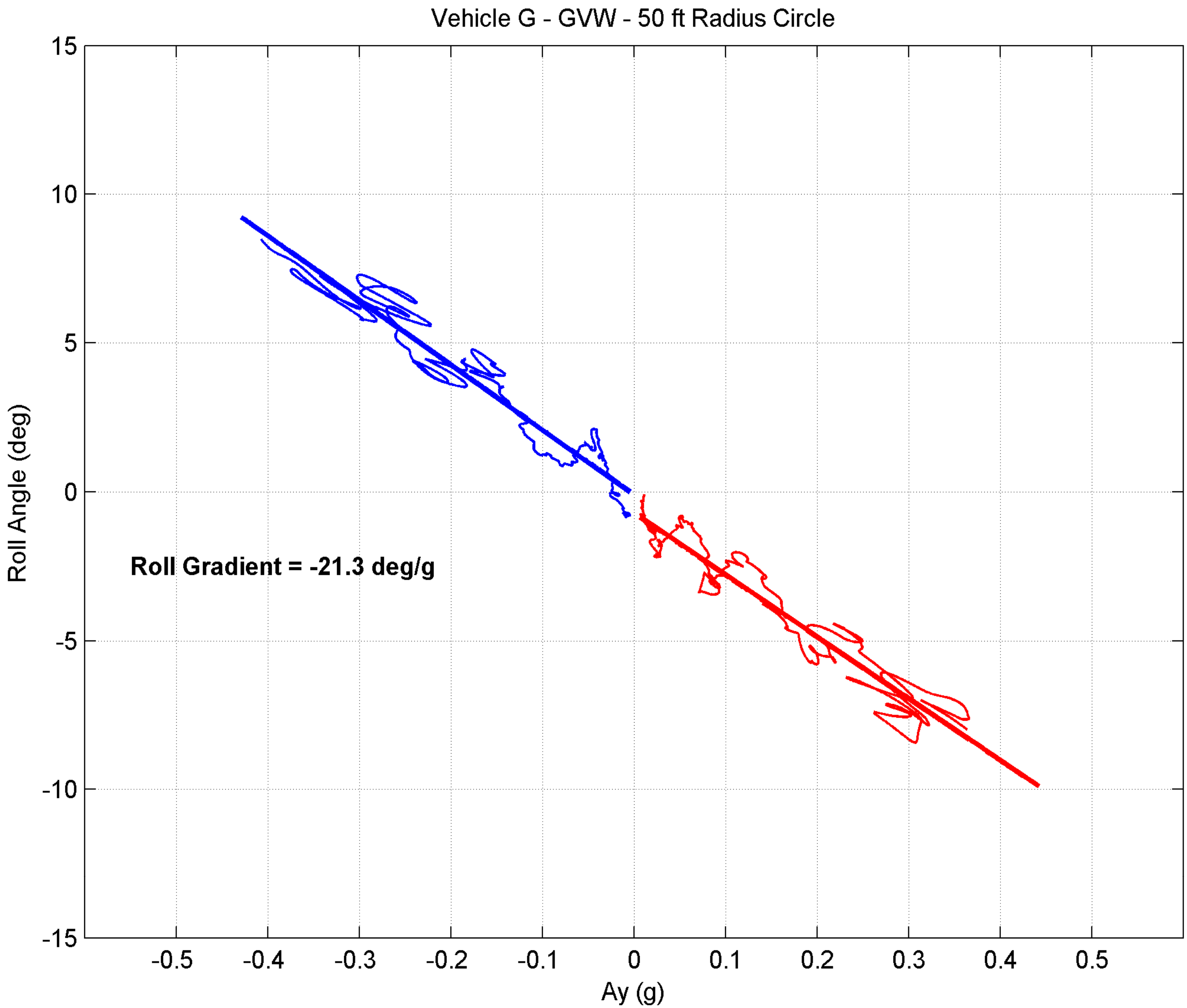


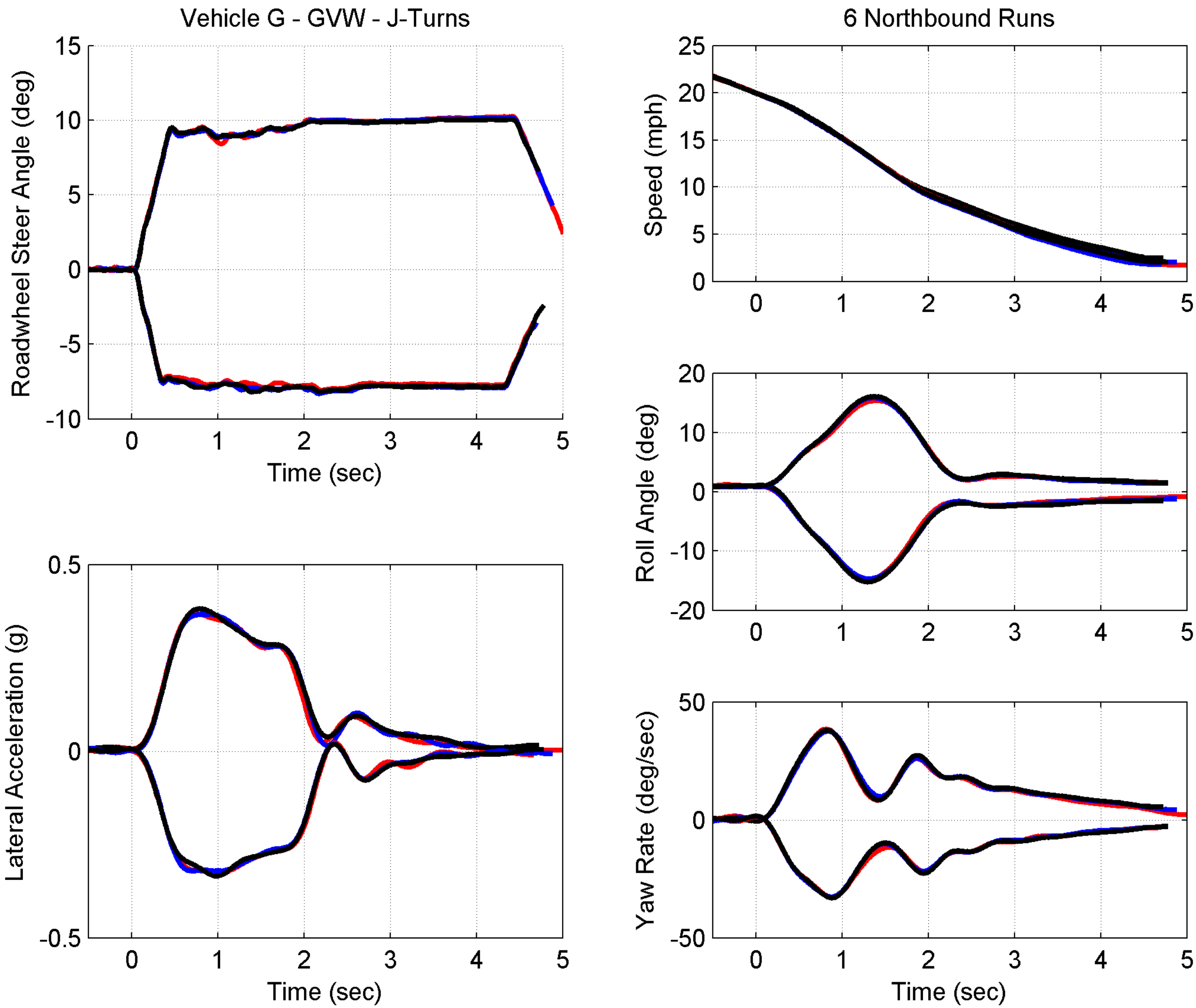
Vehicle G - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
5
0
-5
-10
0
50
100
150
Speed (mph)
25
20
15
10
5
0
CW
CCW
Roll Angle (deg)
-10
Lateral Acceleration (g)
0.6
0.4
0.2
-0.2
-0.4
Time (sec)
Yaw Rate (deg/sec)
40
20
-20
-40
Time (sec)

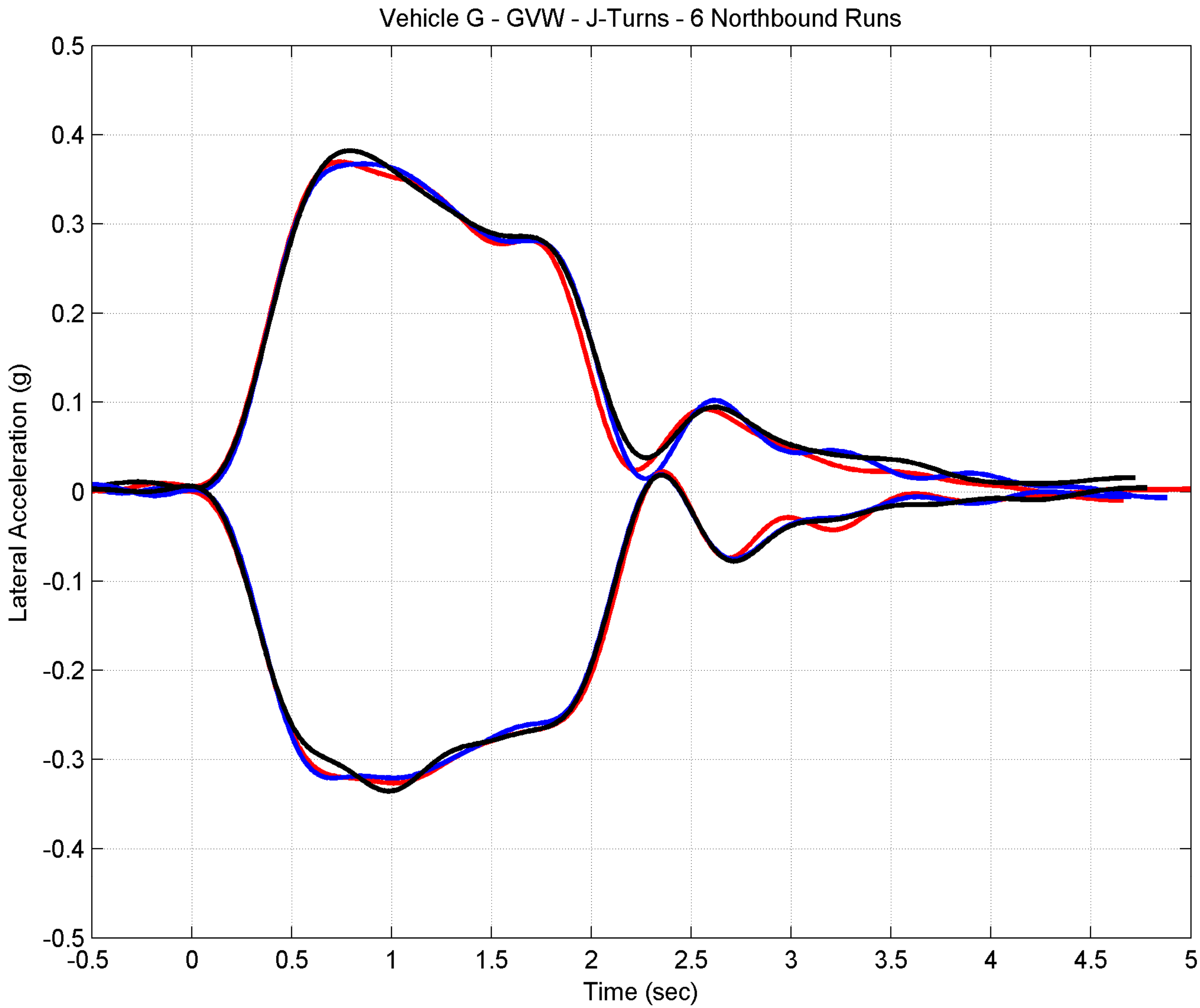

Vehicle G - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)



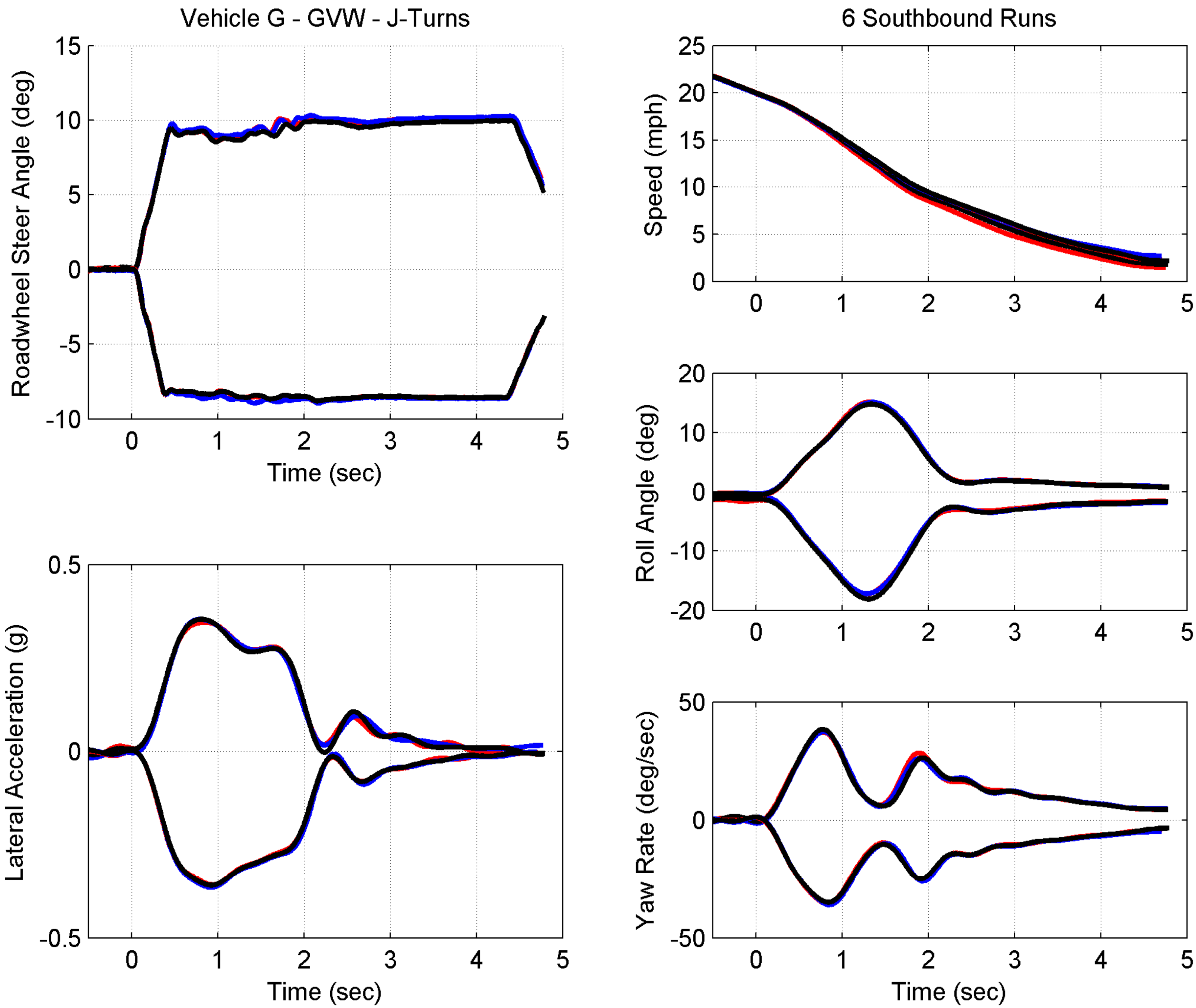
Vehicle G - GVW - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.159 g
CCW Transition to OS
At Ay = -0.13 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

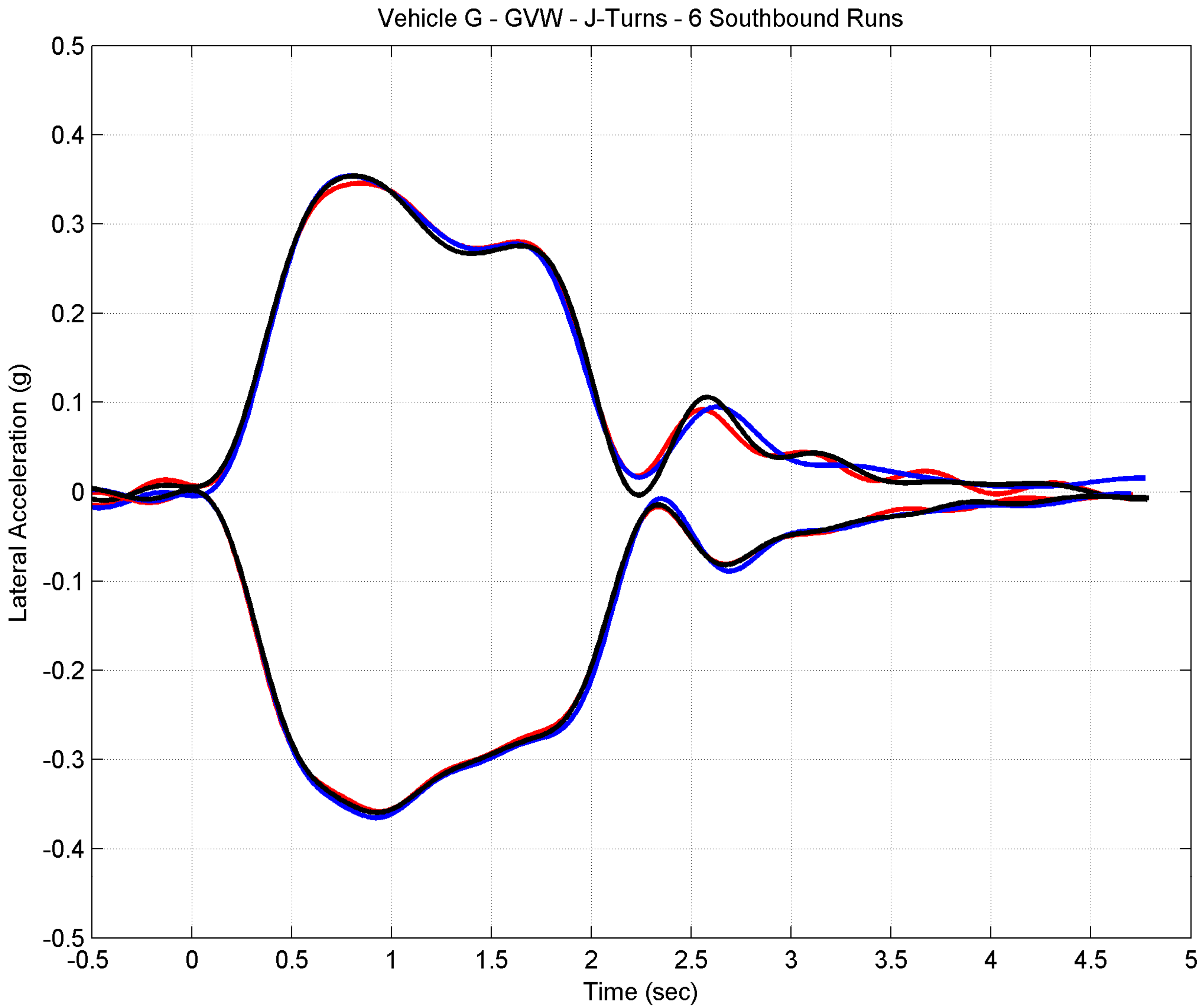

Vehicle G - GVW - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -21.3 deg/g
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5


Vehicle G - GVW - J-Turns
6 Northbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



Vehicle G - GVW - J-Turns - 6 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle G - GVW - J-Turns
6 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle G - GVW - J-Turns - 6 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle G - GVW

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

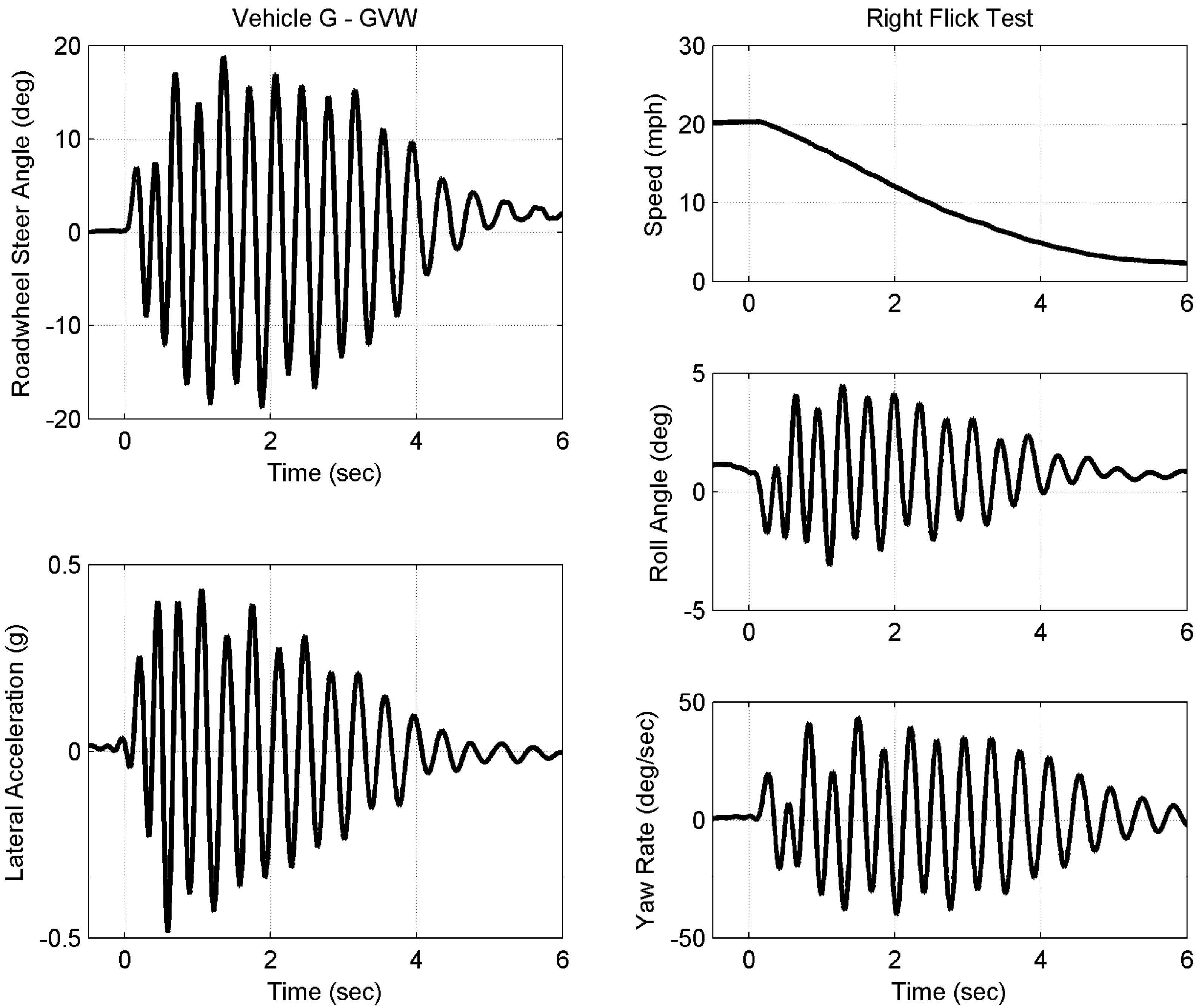
Run Number	Northbound Right Turns	Northbound Left Turns	Average of 6 Northbound Runs
1	0.3695	-0.3265	
2	0.3671	-0.3209	
3	0.3819	-0.3355	
Mean Value of 3 Runs	0.3728	-0.3276	**0.3502**
Standard Deviation of 3 Runs	0.008	0.007	

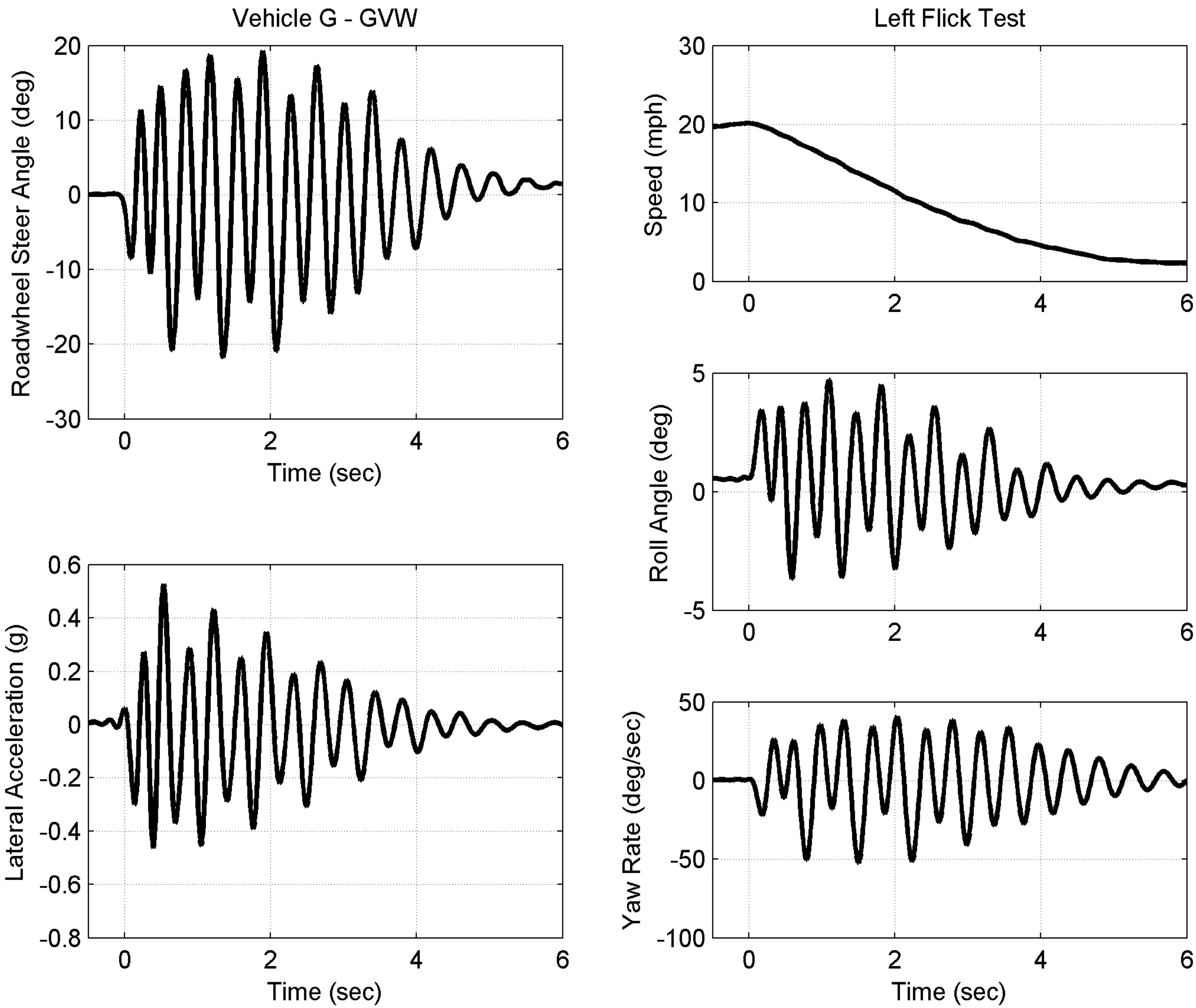
Average of All 12 Runs

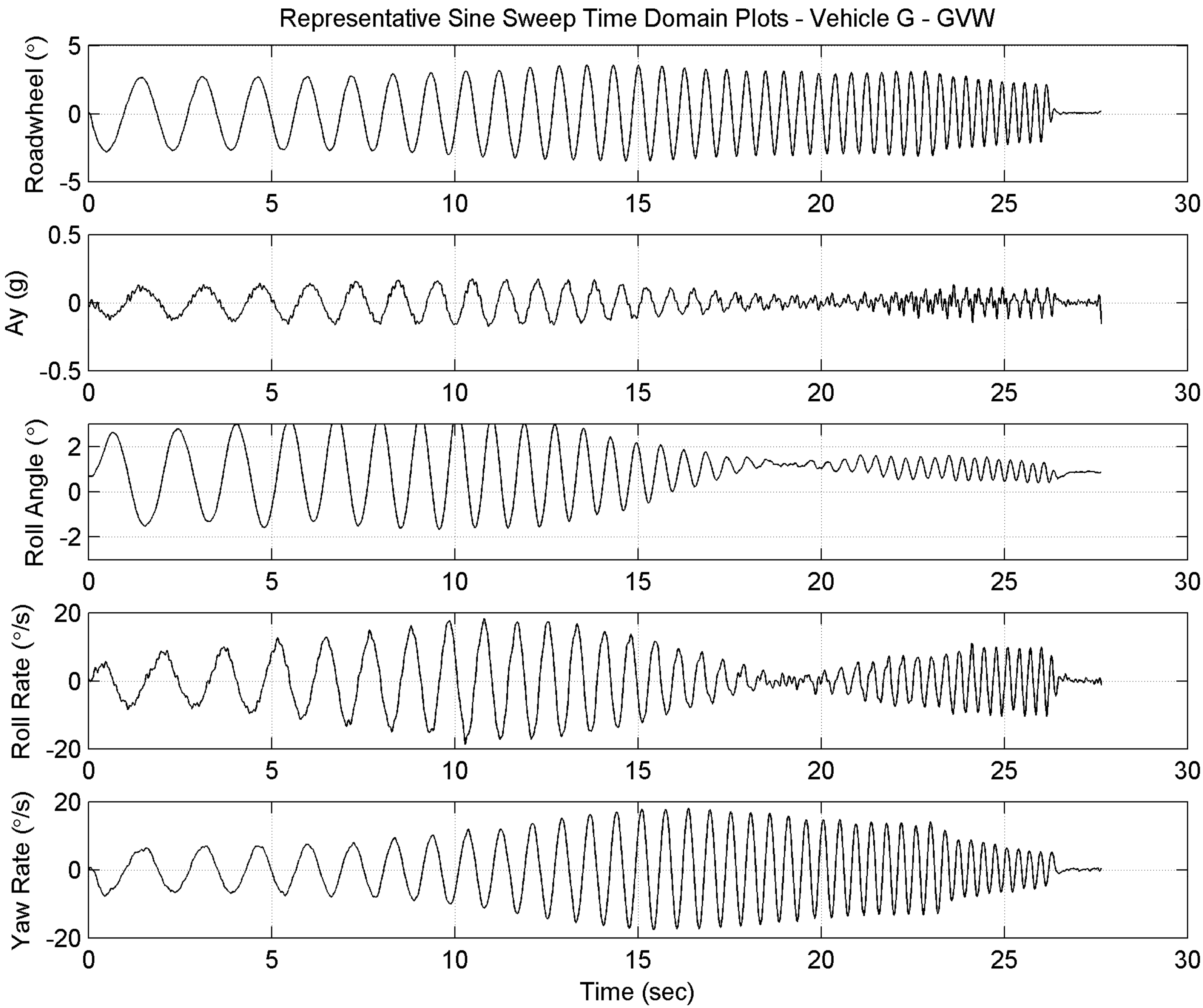
0.353

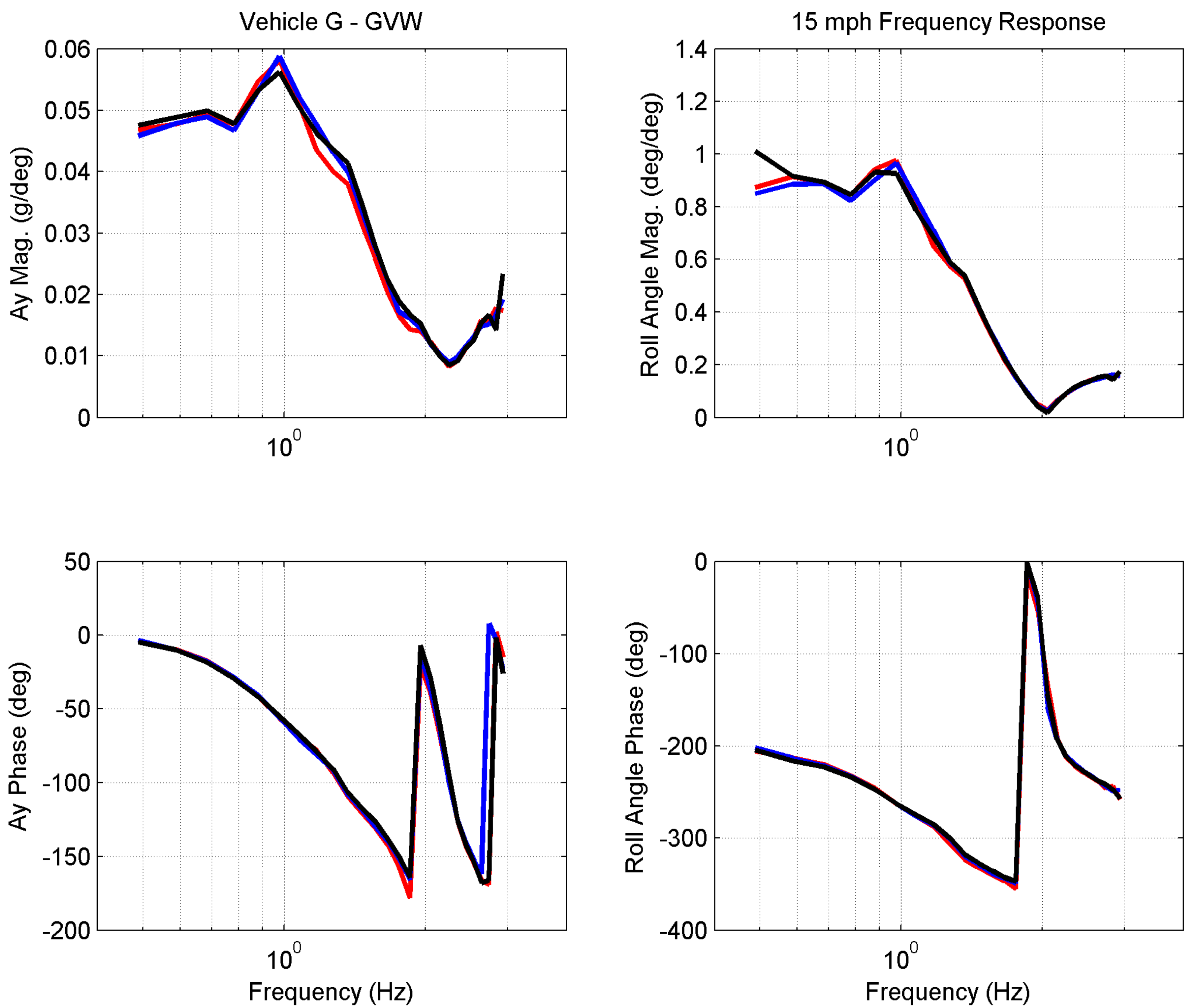
Threshold Ay

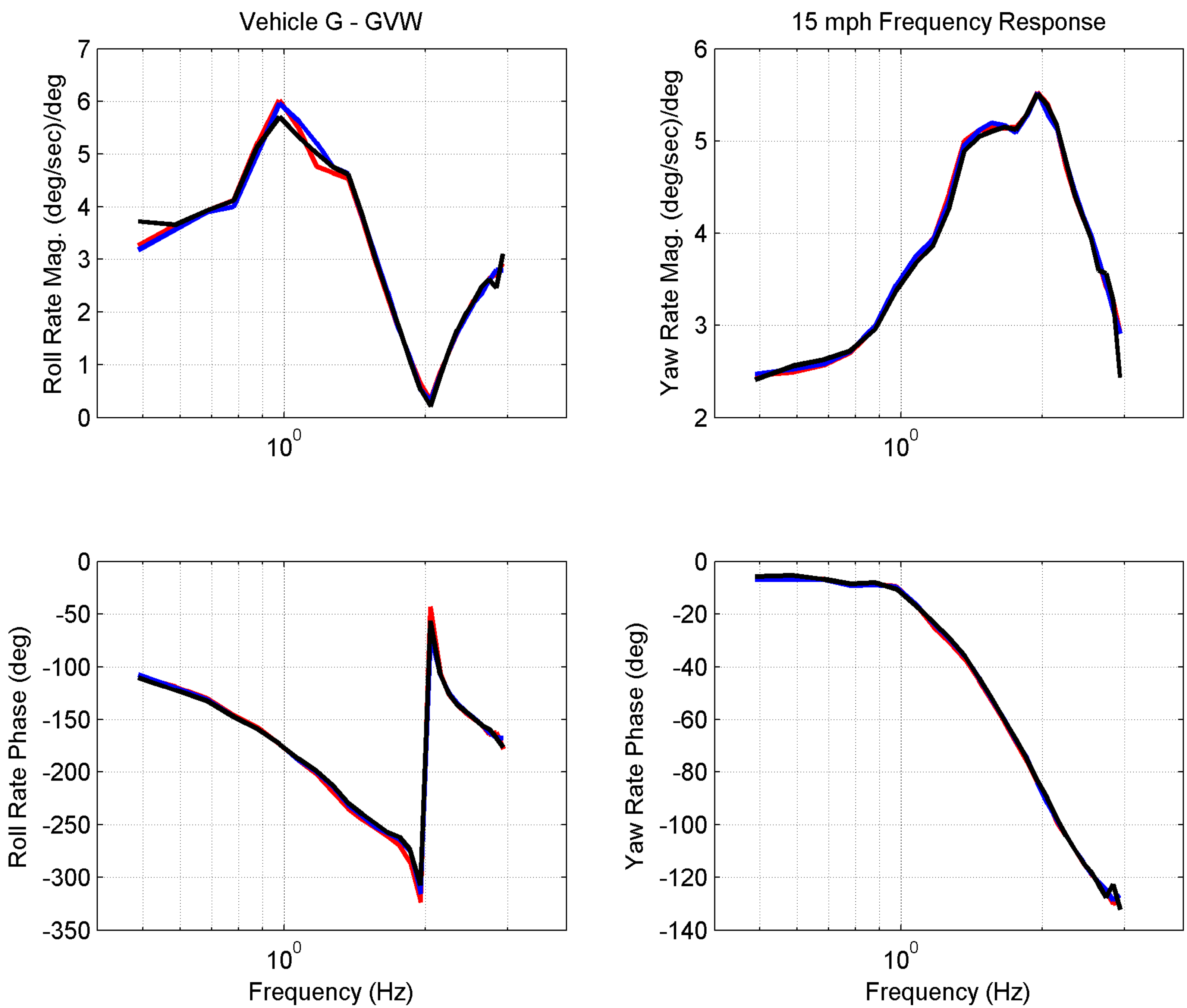
Run Number	Southbound Right Turns	Southbound Left Turns	Average of 6 Southbound Runs
1	0.3454	-0.3584	
2	0.3536	-0.3654	
3	0.3537	-0.3594	
Mean Value of 3 Runs	0.3509	-0.3611	**0.3560**
Standard Deviation of 3 Runs	0.005	0.004	

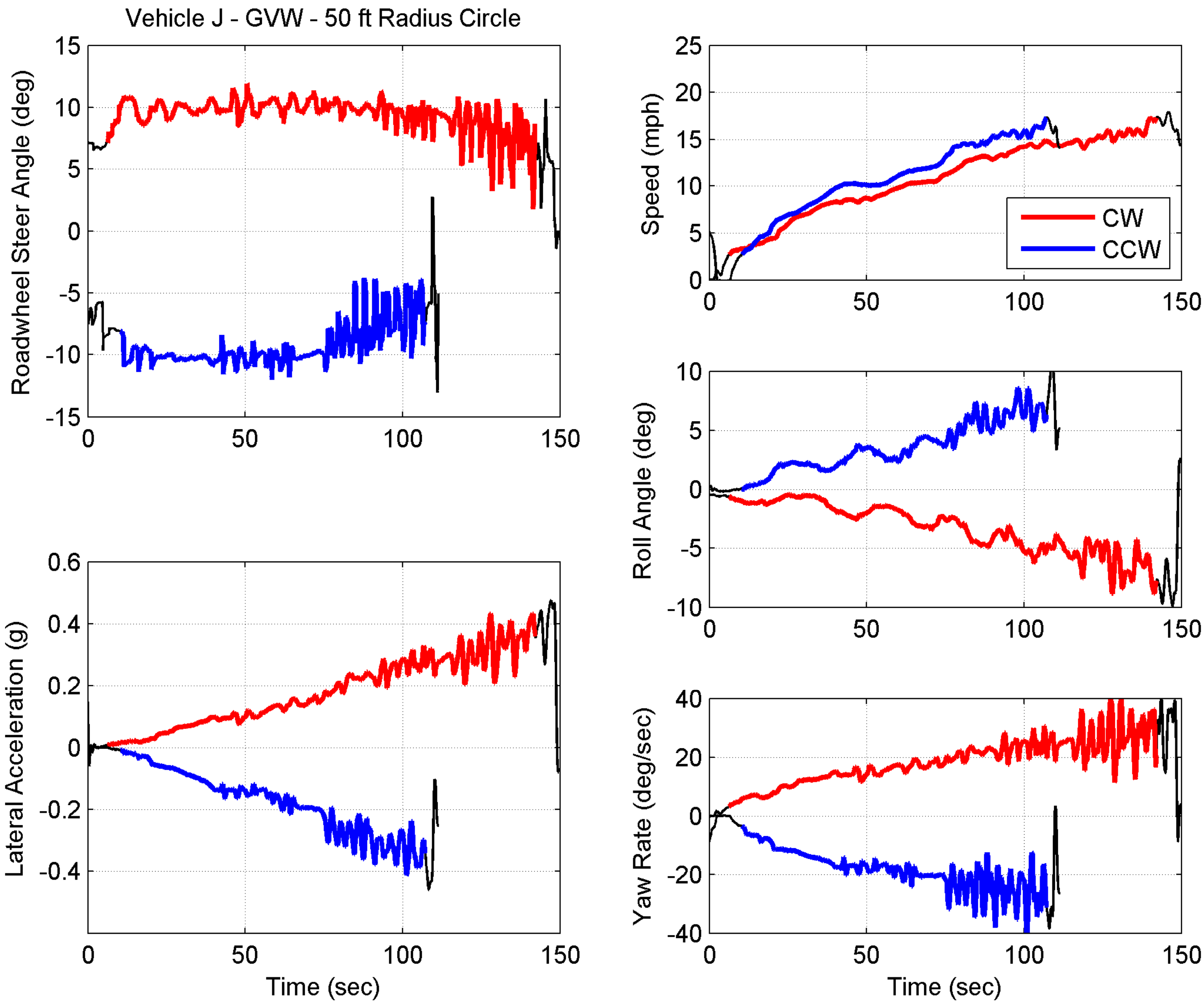

Vehicle G - GVW
Right Flick Test
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
2
4
6
Time (sec)
Speed (mph)
30
20
10
0
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
50
0
-50

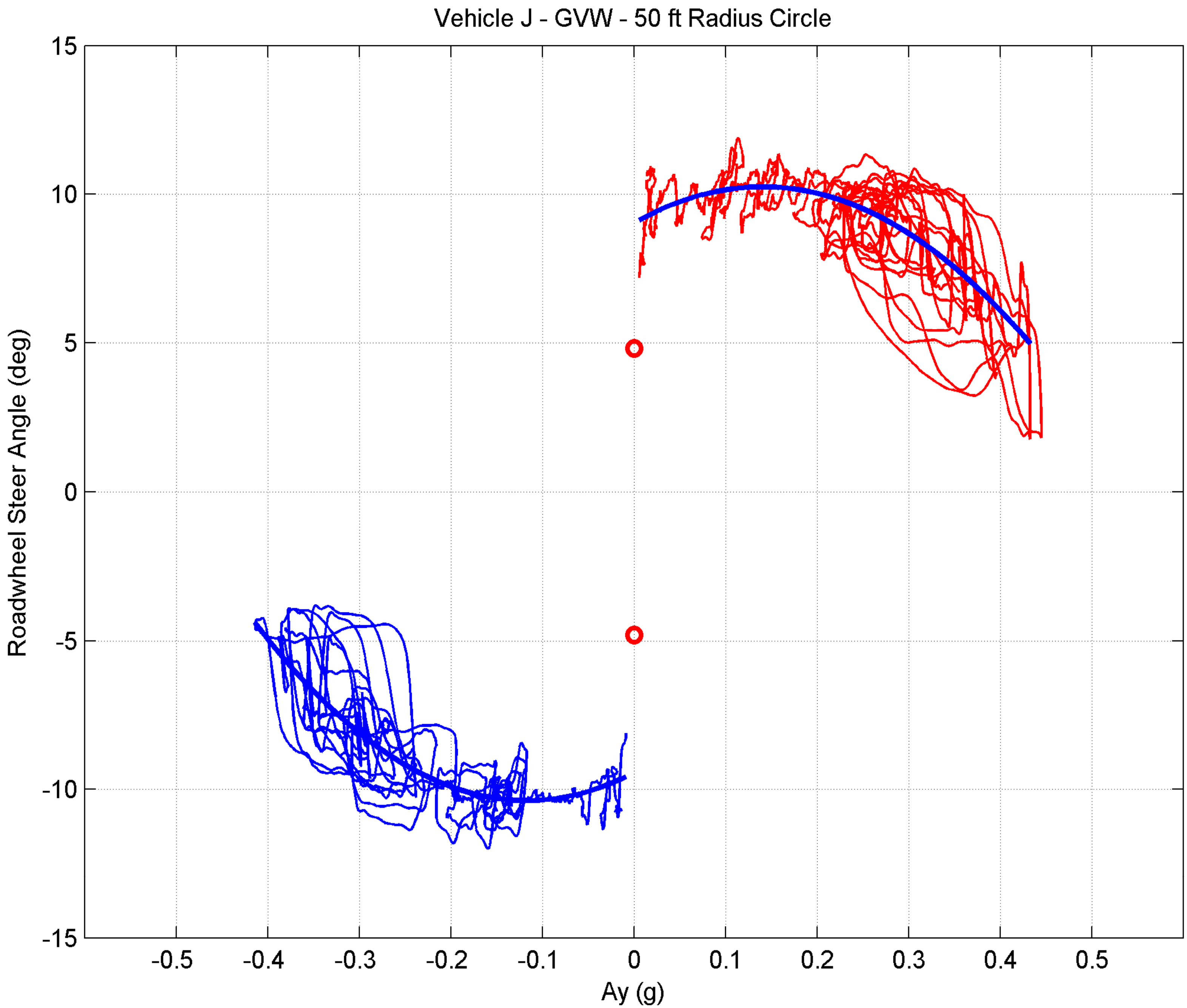

Vehicle G - GVW
Left Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Representative Sine Sweep Time Domain Plots - Vehicle G - GVW
Roadwheel (°)
5
0
-5
Ay (g)
0.5
0
-0.5
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
20
0
-20
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)

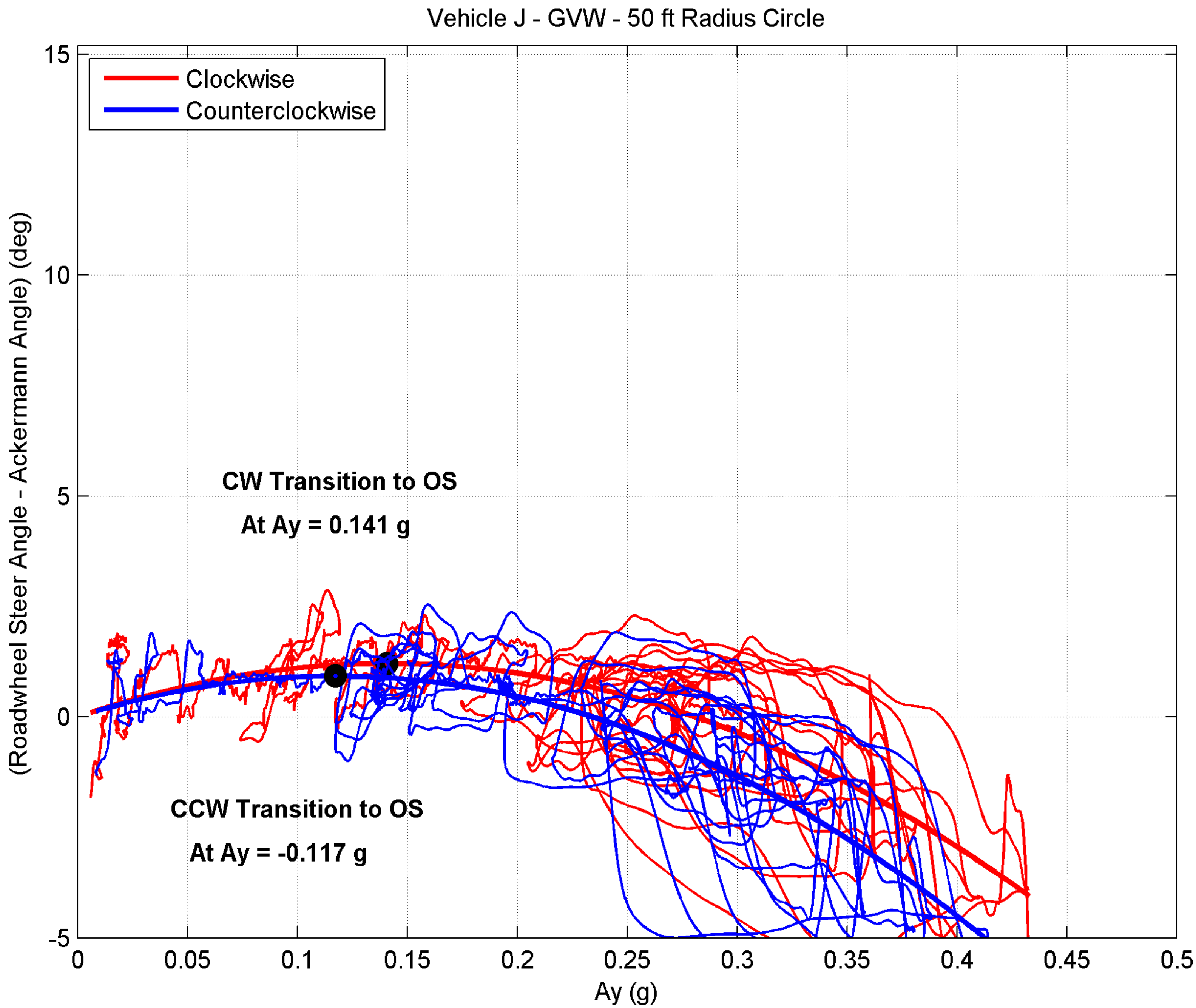

Vehicle G - GVW
15 mph Frequency Response
Ay Mag. (g/deg)
0.06
0.05
0.04
0.03
0.02
0.01
0
10^0
Roll Angle Mag. (deg/deg)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10^0
Ay Phase (deg)
50
0
-50
-100
-150
-200
10^0
Frequency (Hz)
Roll Angle Phase (deg)
0
-100
-200
-300
-400
10^0
Frequency (Hz)

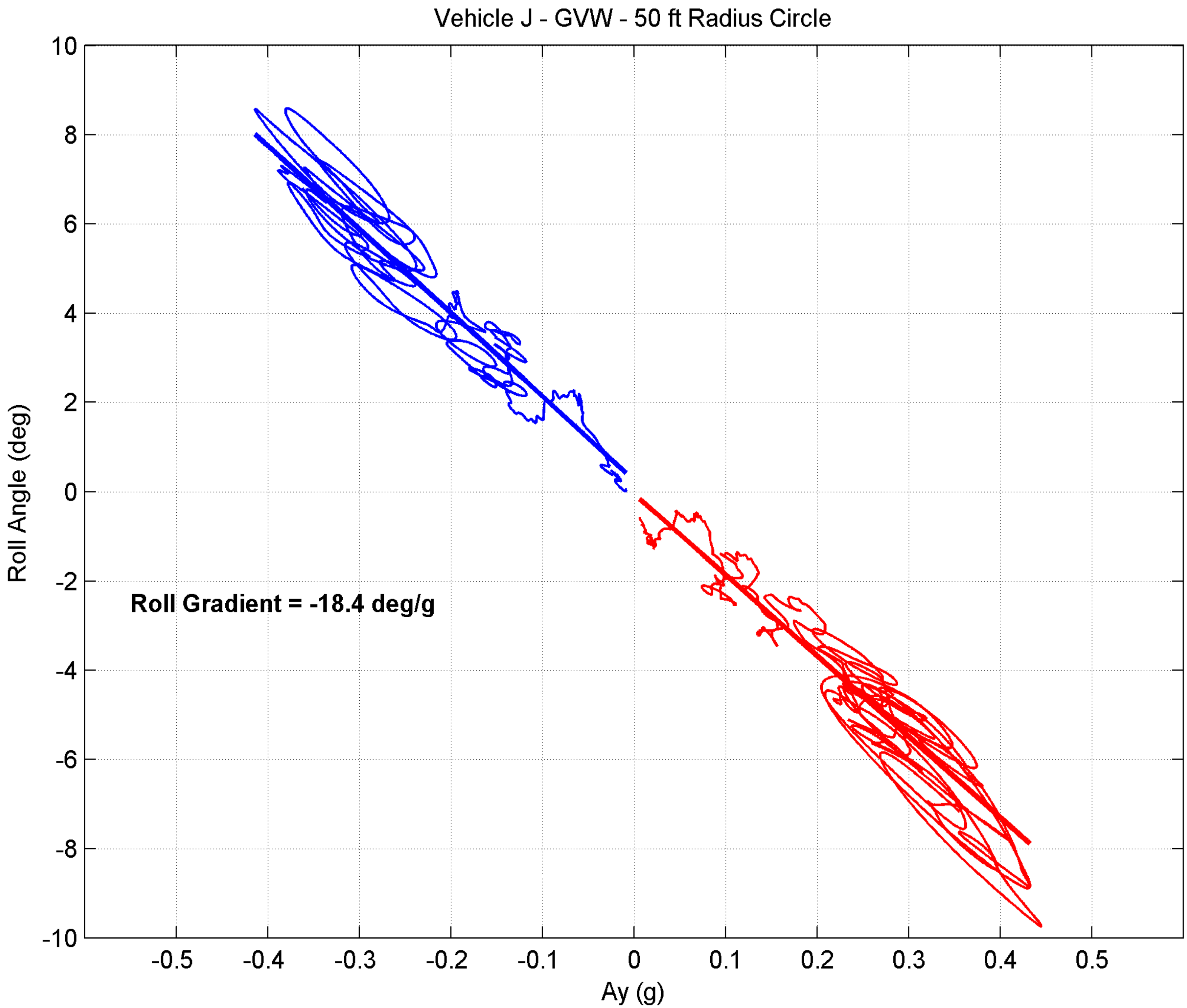

Vehicle G - GVW
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)

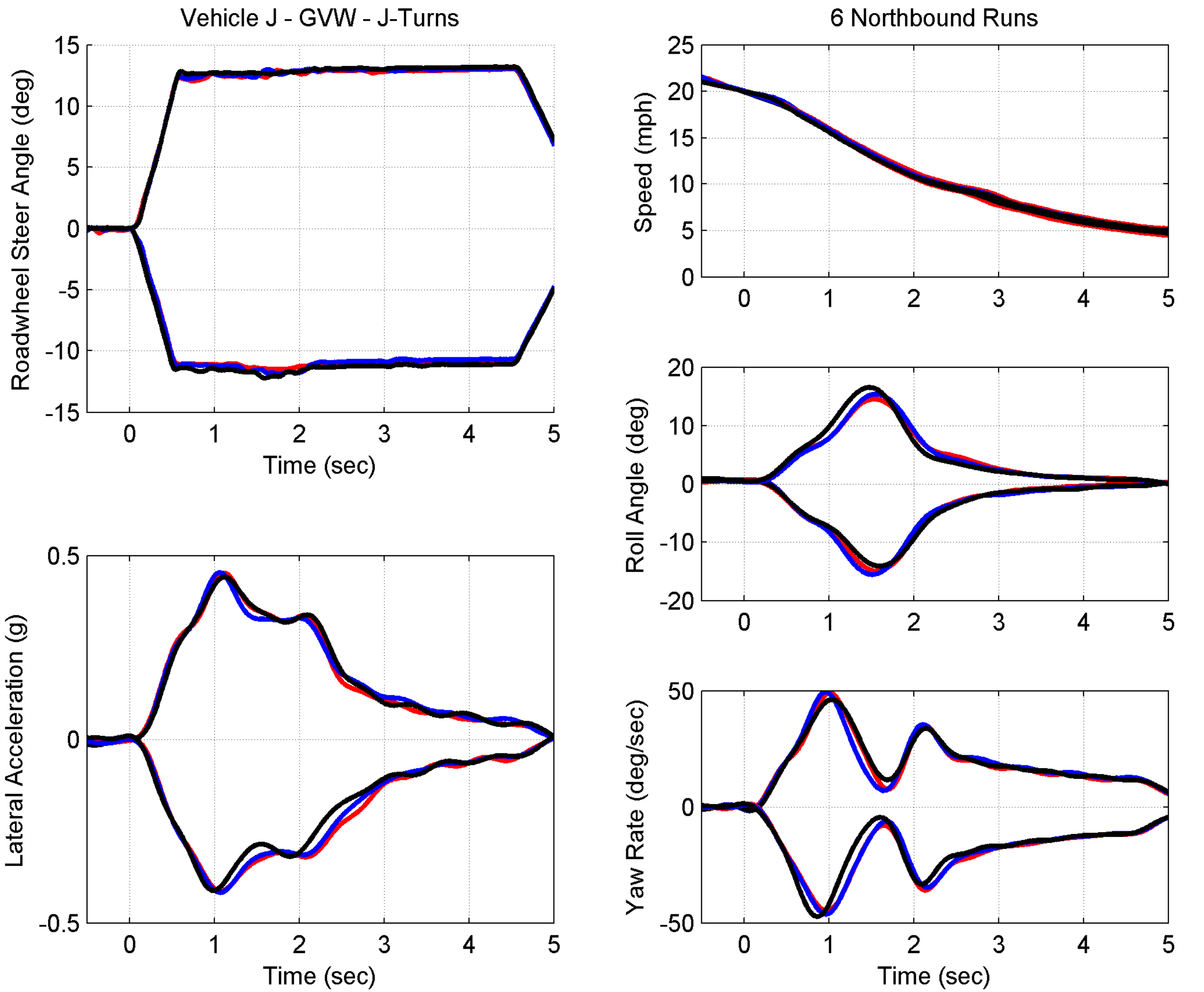

Vehicle J - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
50
100
150
Speed (mph)
25
20
15
10
5
0
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
0.6
0.4
0.2
-0.2
-0.4
Time (sec)
Yaw Rate (deg/sec)
40
20
-20
-40
Time (sec)

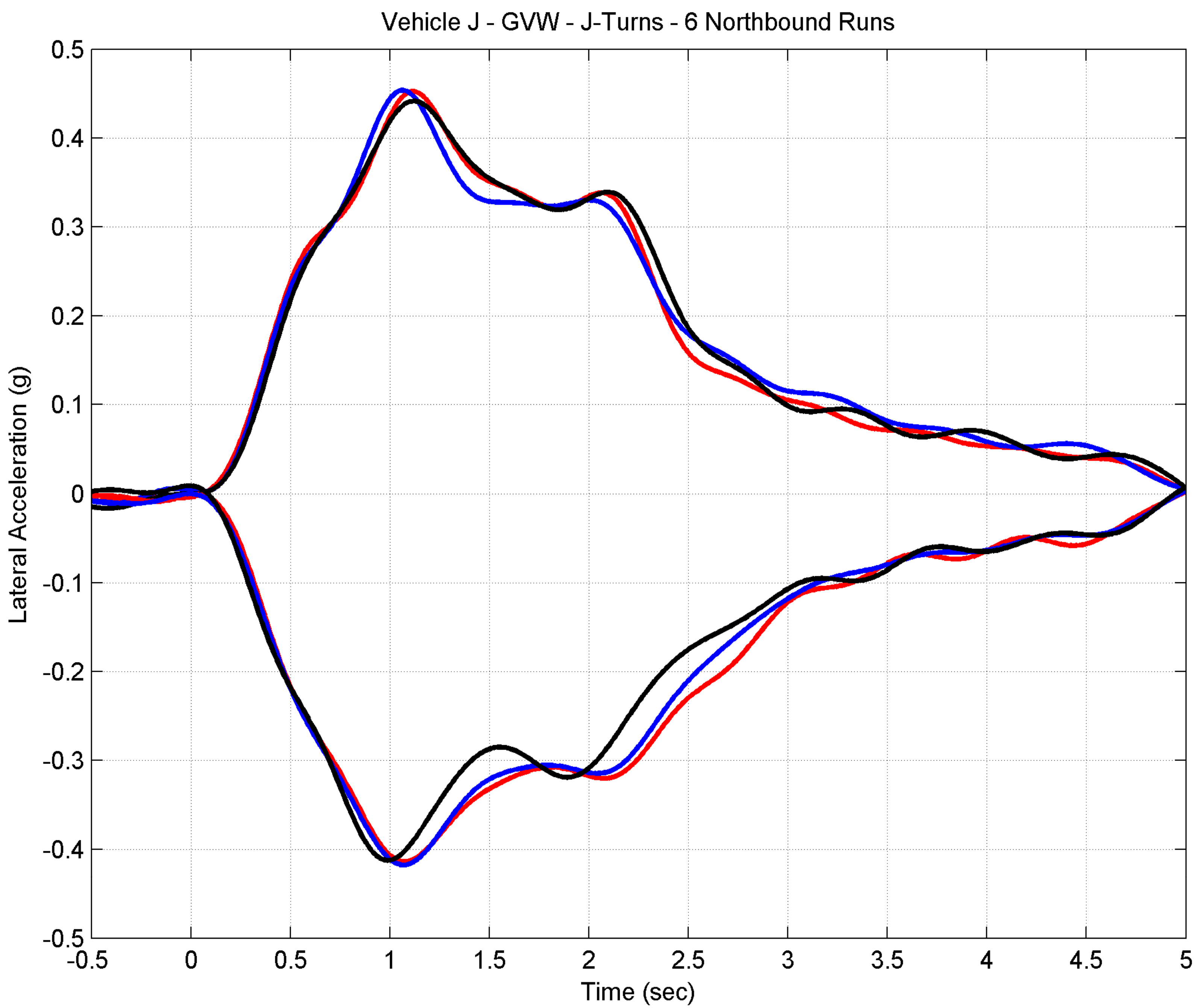


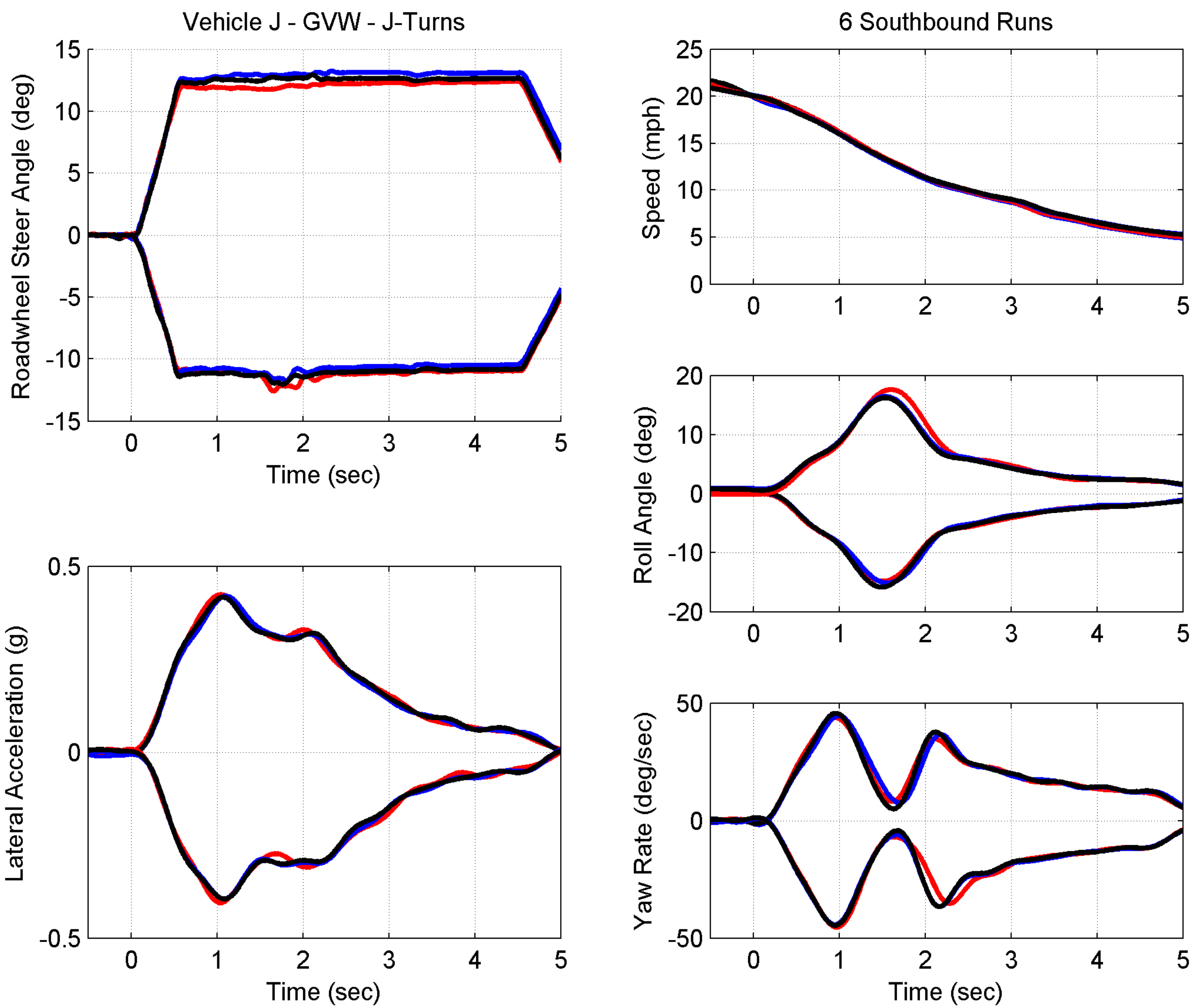
Vehicle J - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5


Vehicle J - GVW - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.141 g
CCW Transition to OS
At Ay = -0.117 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

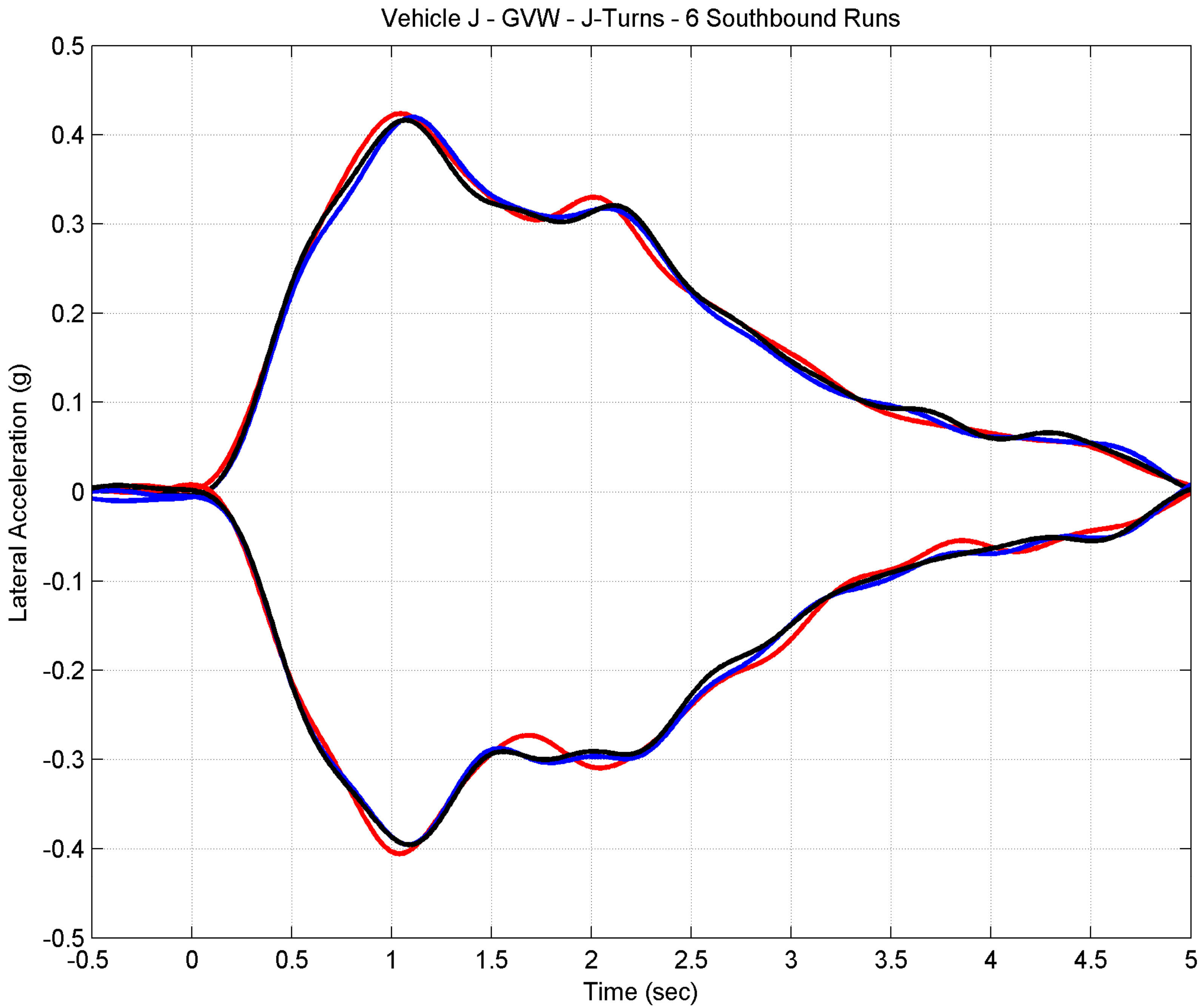

Vehicle J - GVW - 50 ft Radius Circle
10
8
6
4
2
0
-2
-4
-6
-8
-10
Roll Angle (deg)
Roll Gradient = -18.4 deg/g
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)


Vehicle J - GVW - J-Turns
6 Northbound Runs
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0 1 2 3 4 5
Time (sec)
Speed (mph)
25
20
15
10
5
0
0 1 2 3 4 5
Roll Angle (deg)
20
10
0
-10
-20
0 1 2 3 4 5
Lateral Acceleration (g)
0.5
0
-0.5
0 1 2 3 4 5
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
0 1 2 3 4 5
Time (sec)


Vehicle J - GVW - J-Turns - 6 Northbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)



Vehicle J - GVW - J-Turns
6 Southbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



Vehicle J - GVW - J-Turns - 6 Southbound Runs
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle J - GVW

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

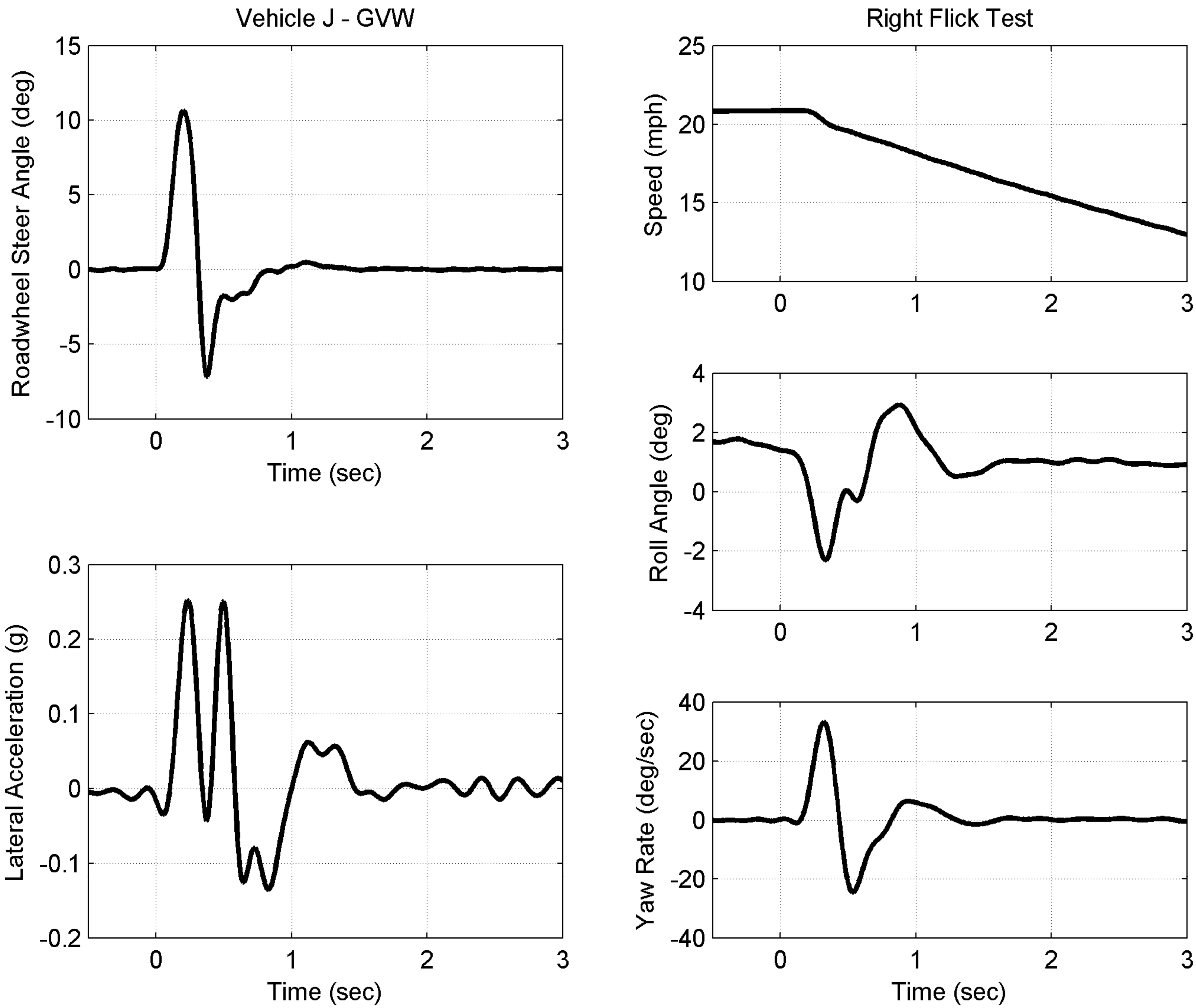
Run Number	Northbound Right Turns	Northbound Left Turns	Average of 6 Northbound Runs
1	0.4525	-0.4139	
2	0.4537	-0.4178	
3	0.4418	-0.4125	
Mean Value of 3 Runs	0.4493	-0.4147	**0.4320**
Standard Deviation of 3 Runs	0.007	0.003	

Run Number	Southbound Right Turns	Southbound Left Turns	Average of 6 Southbound Runs
1	0.4238	-0.4057	
2	0.4199	-0.3955	
3	0.4165	-0.3957	
Mean Value of 3 Runs	0.4201	-0.3990	**0.4095**
Standard Deviation of 3 Runs	0.004	0.006	

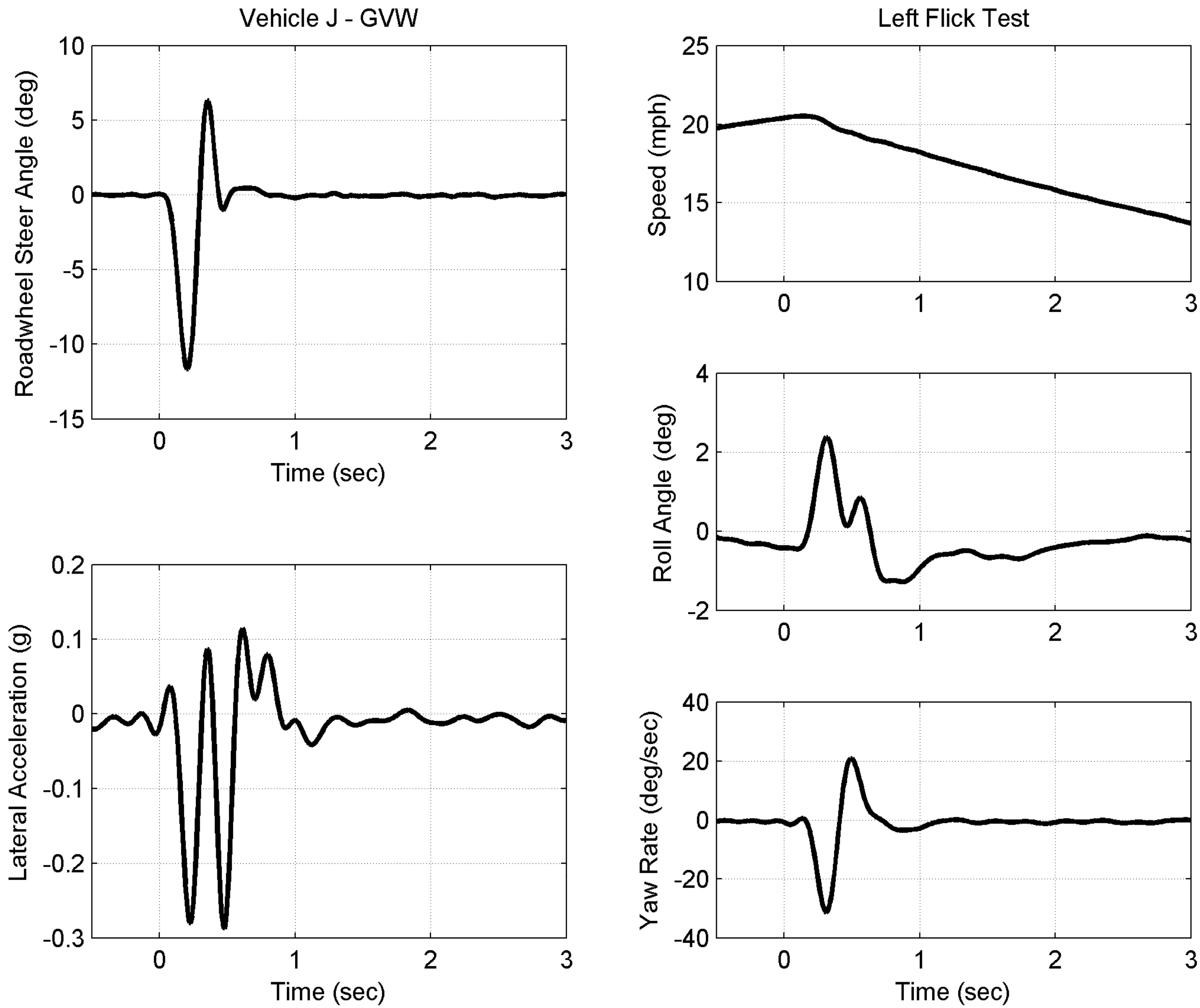
Average of All 12 Runs

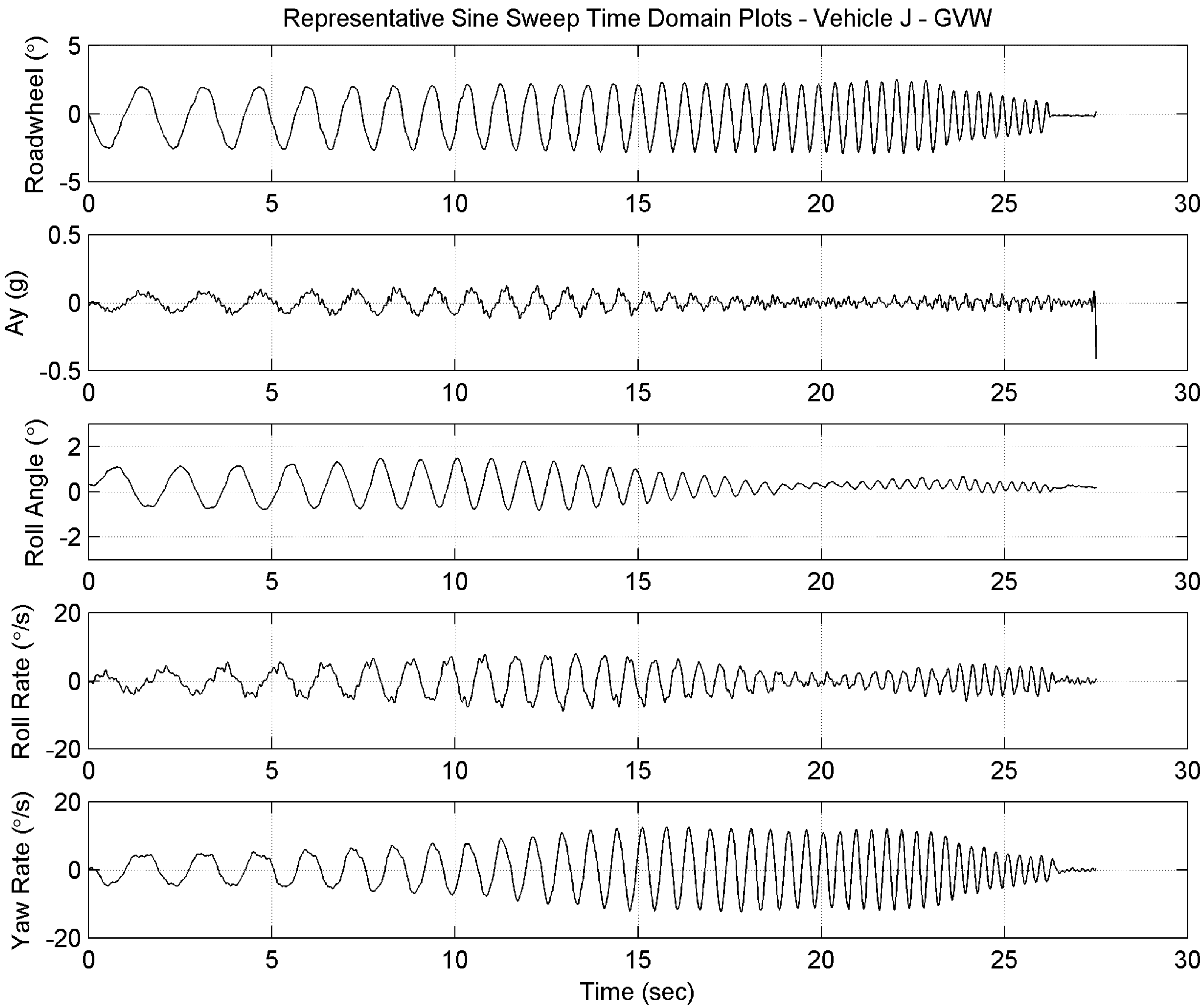
0.421

Threshold Ay

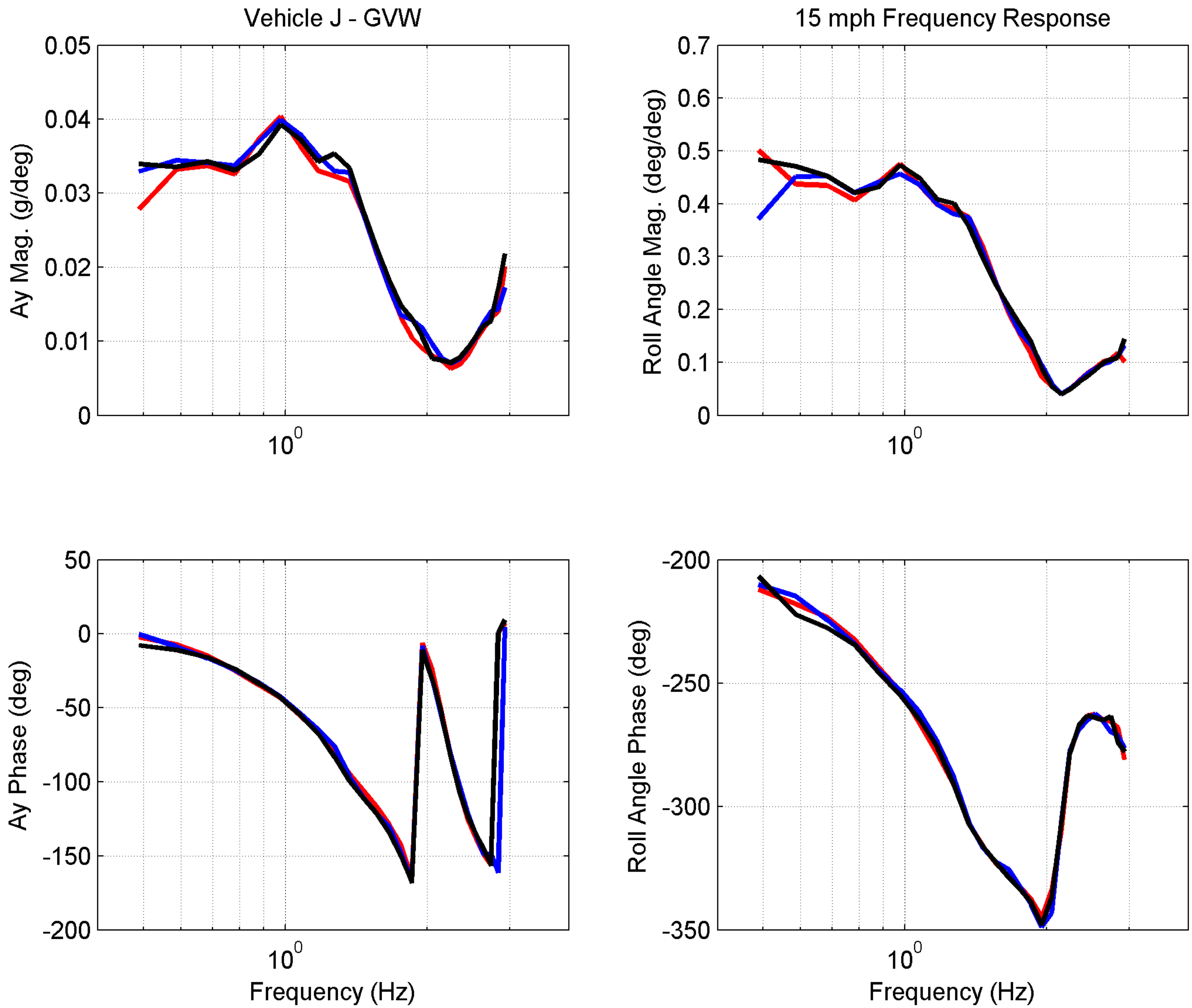


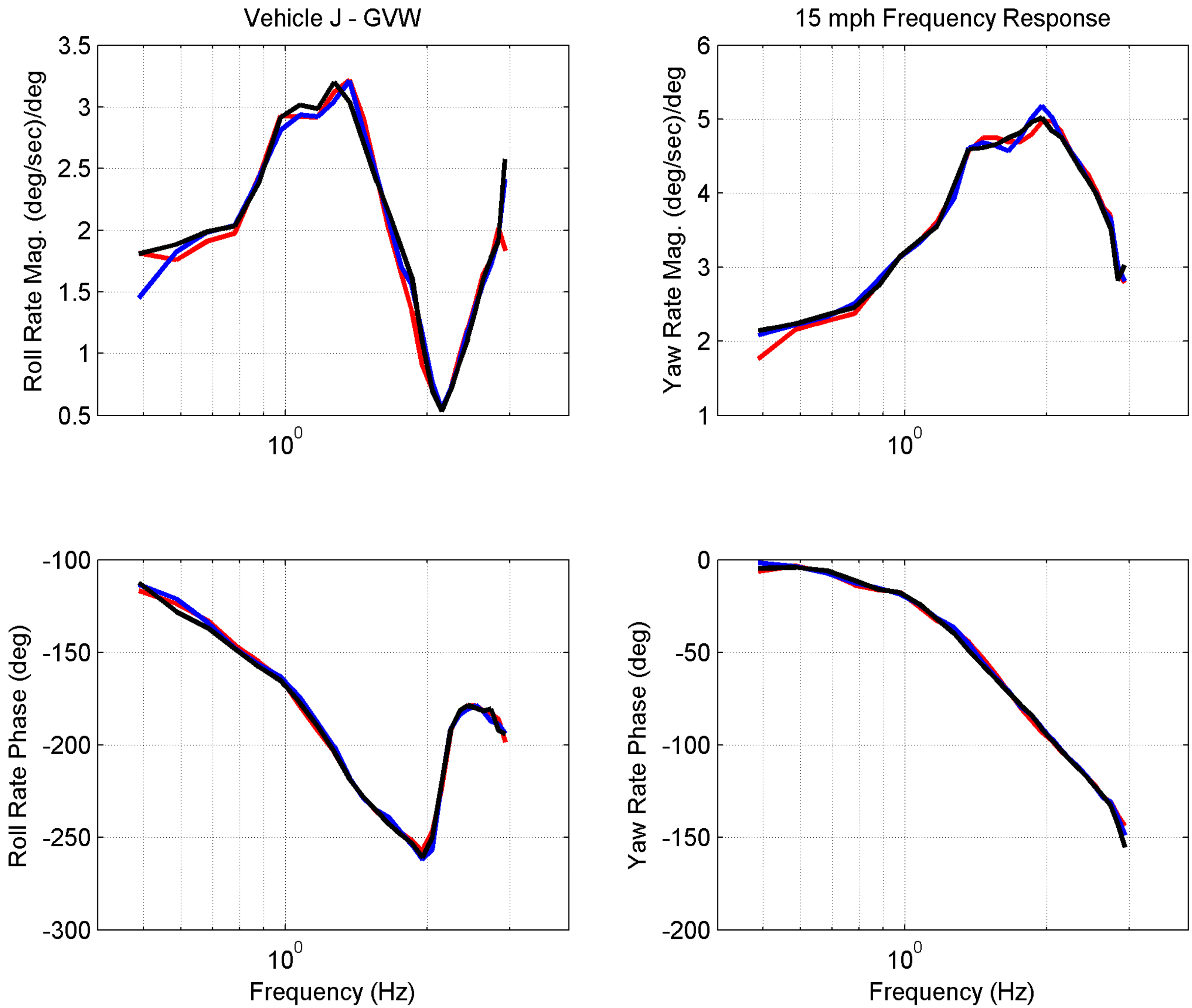
Vehicle J - GVW
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

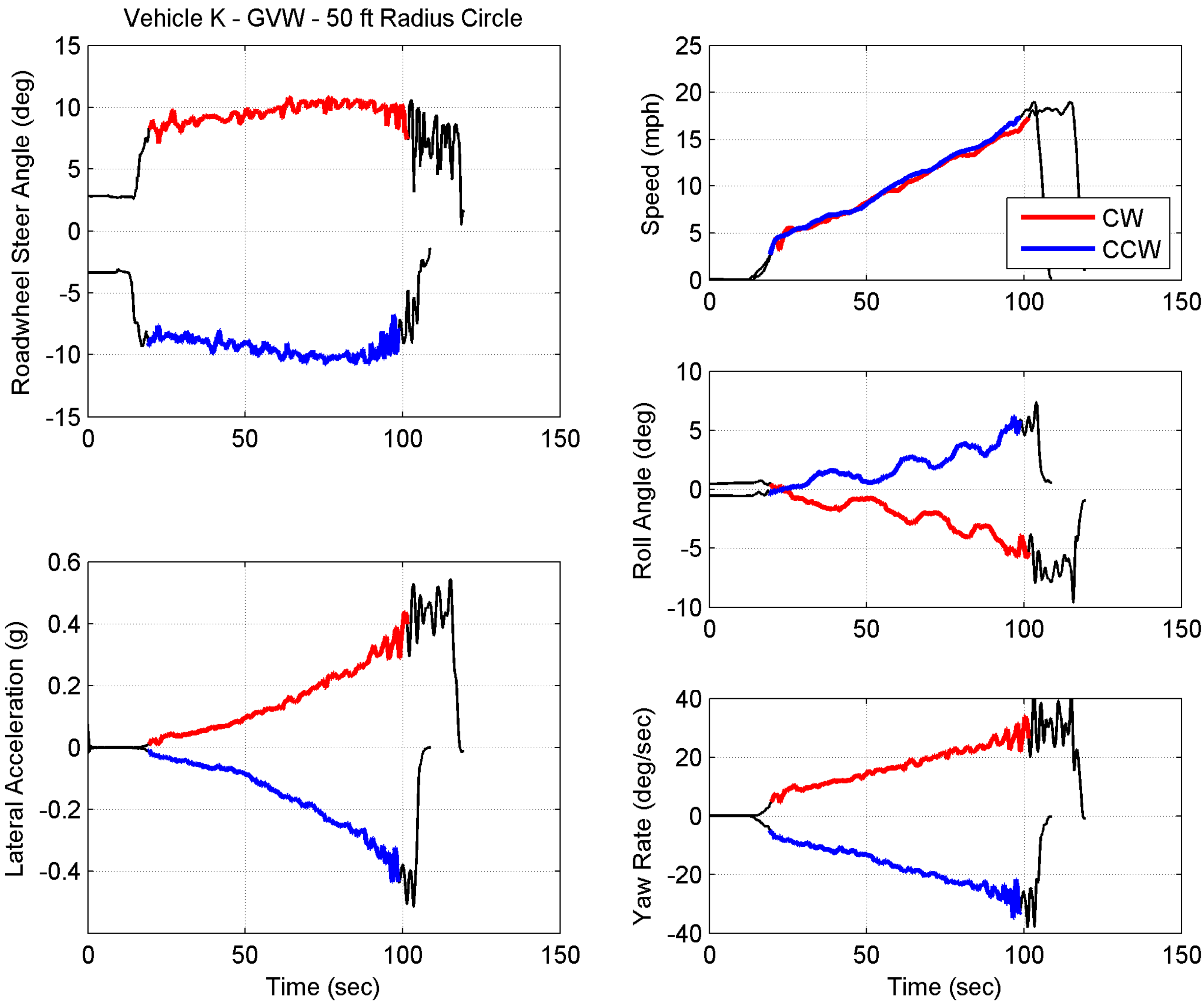

Vehicle J - GVW
Left Flick Test
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



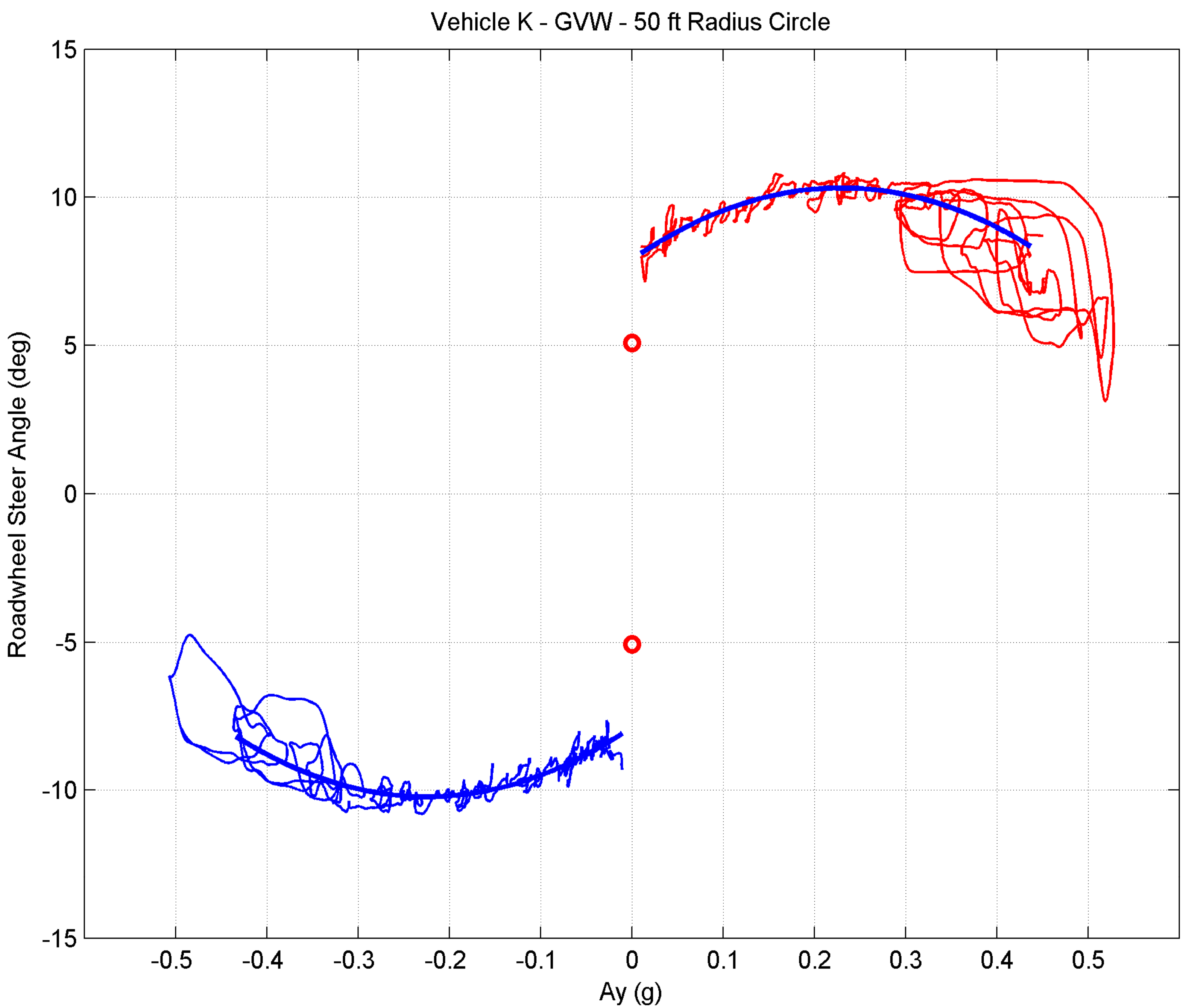
Representative Sine Sweep Time Domain Plots - Vehicle J - GVW
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

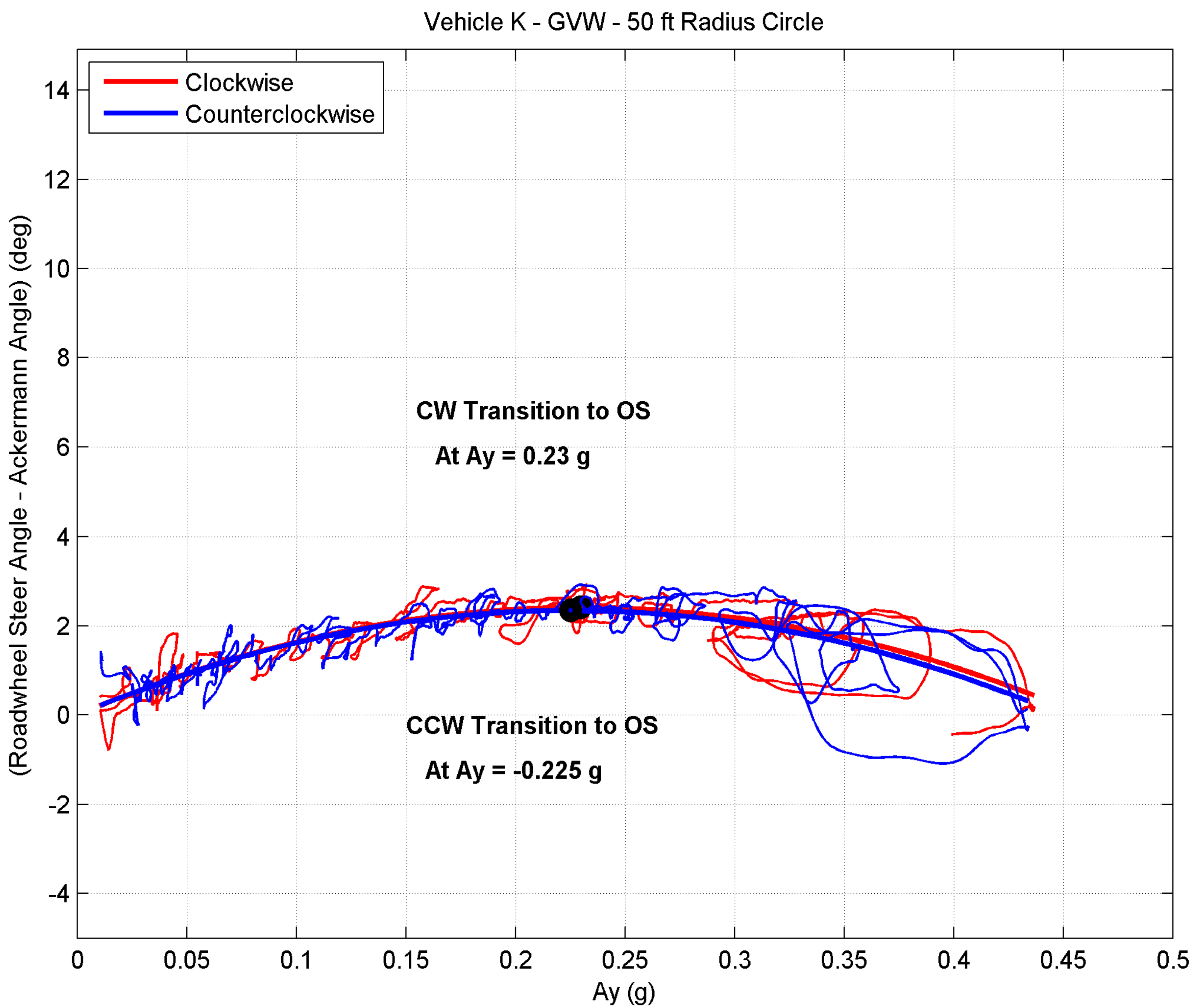

Vehicle J - GVW
15 mph Frequency Response
Ay Mag. (g/deg)
0.05
0.04
0.03
0.02
0.01
0
10^0
Roll Angle Mag. (deg/deg)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10^0
Ay Phase (deg)
50
0
-50
-100
-150
-200
10^0
Frequency (Hz)
Roll Angle Phase (deg)
-200
-250
-300
-350
10^0
Frequency (Hz)

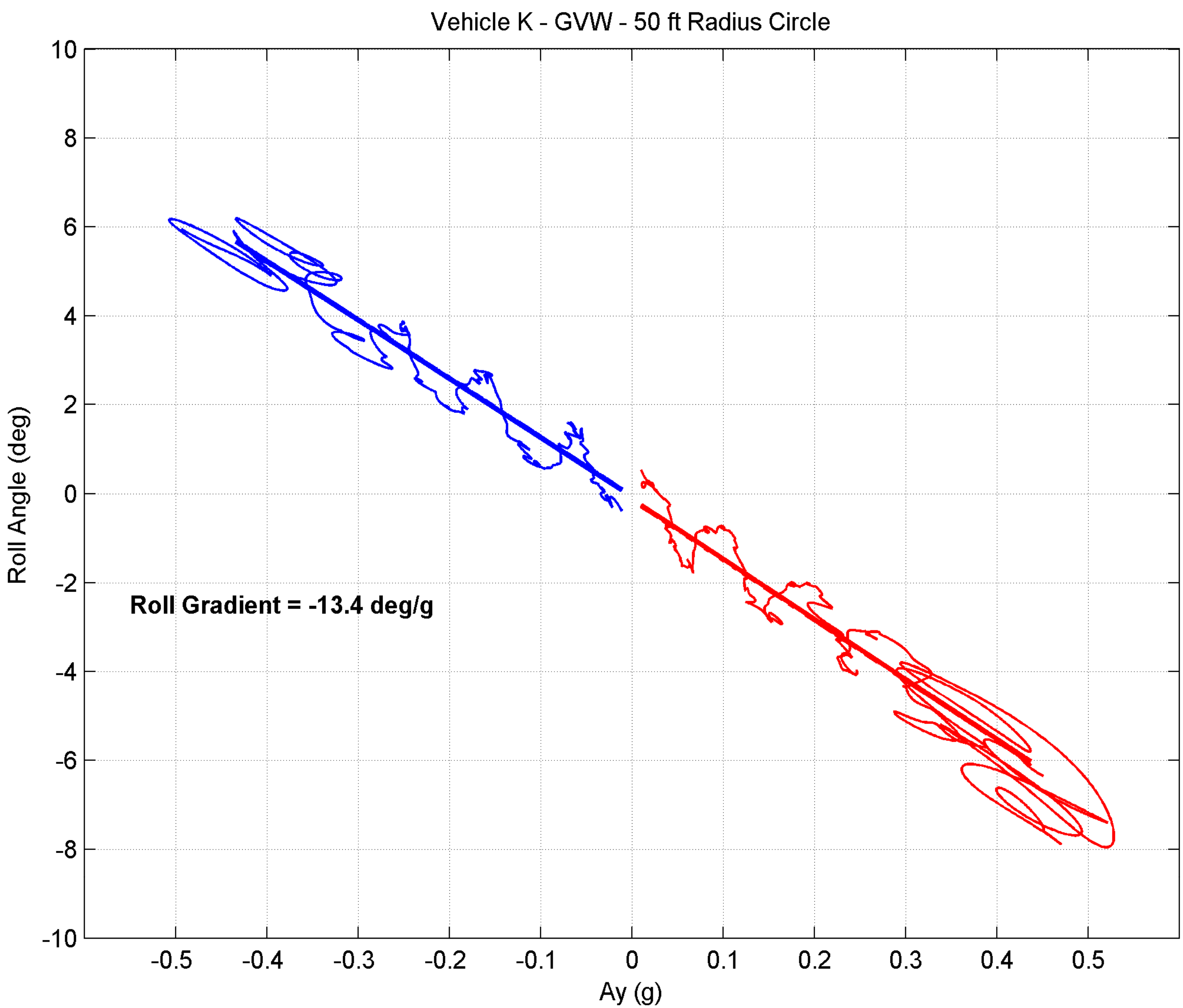

Vehicle J - GVW
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
10^0
3.5
3
2.5
2
1.5
1
0.5
6
5
4
3
2
1
-100
-150
-200
-250
-300
0
-50
-100
-150
-200



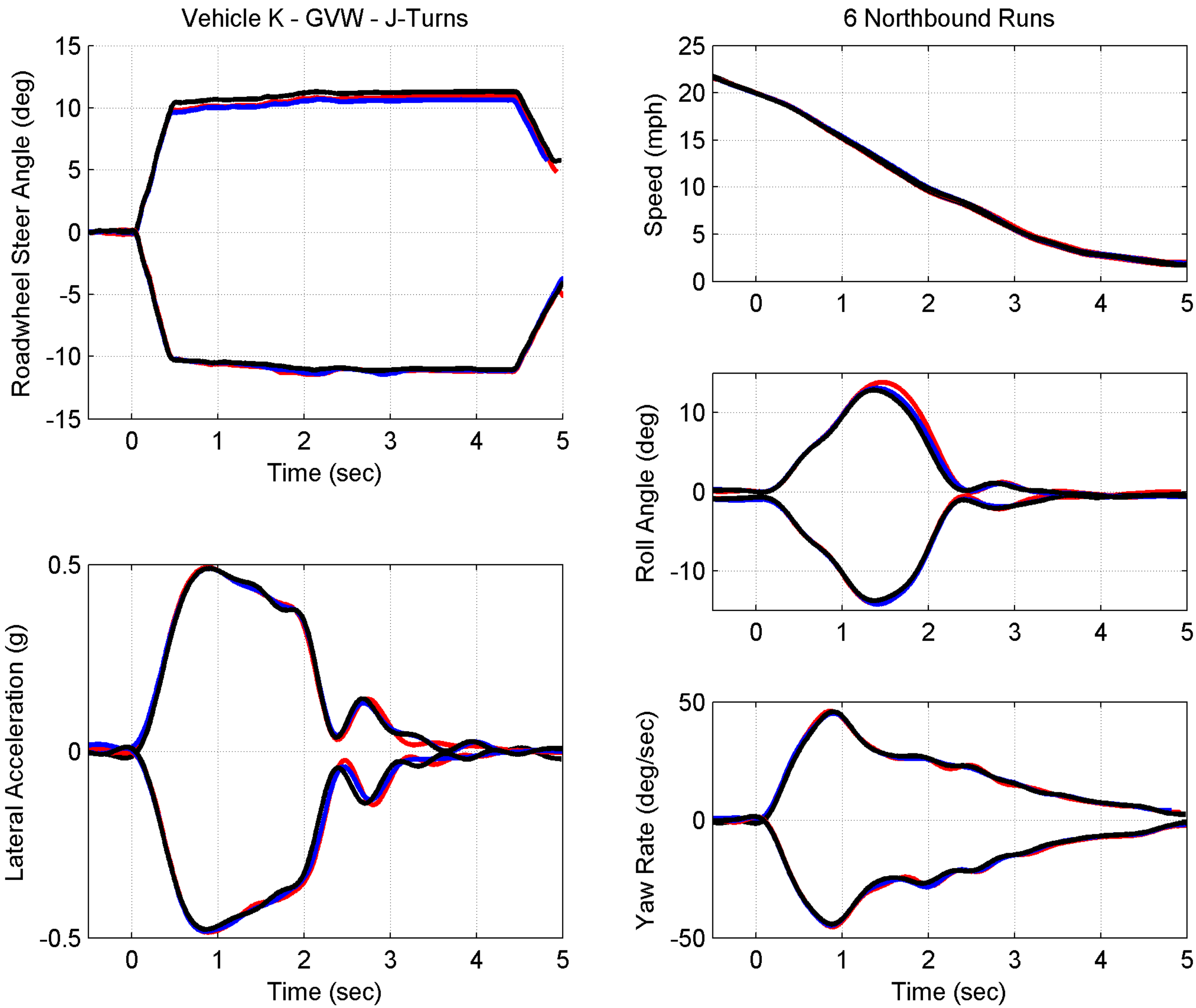
Vehicle K - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
50
100
150
Speed (mph)
25
20
15
10
5
0
CW
CCW
Roll Angle (deg)
10
5
0
-5
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

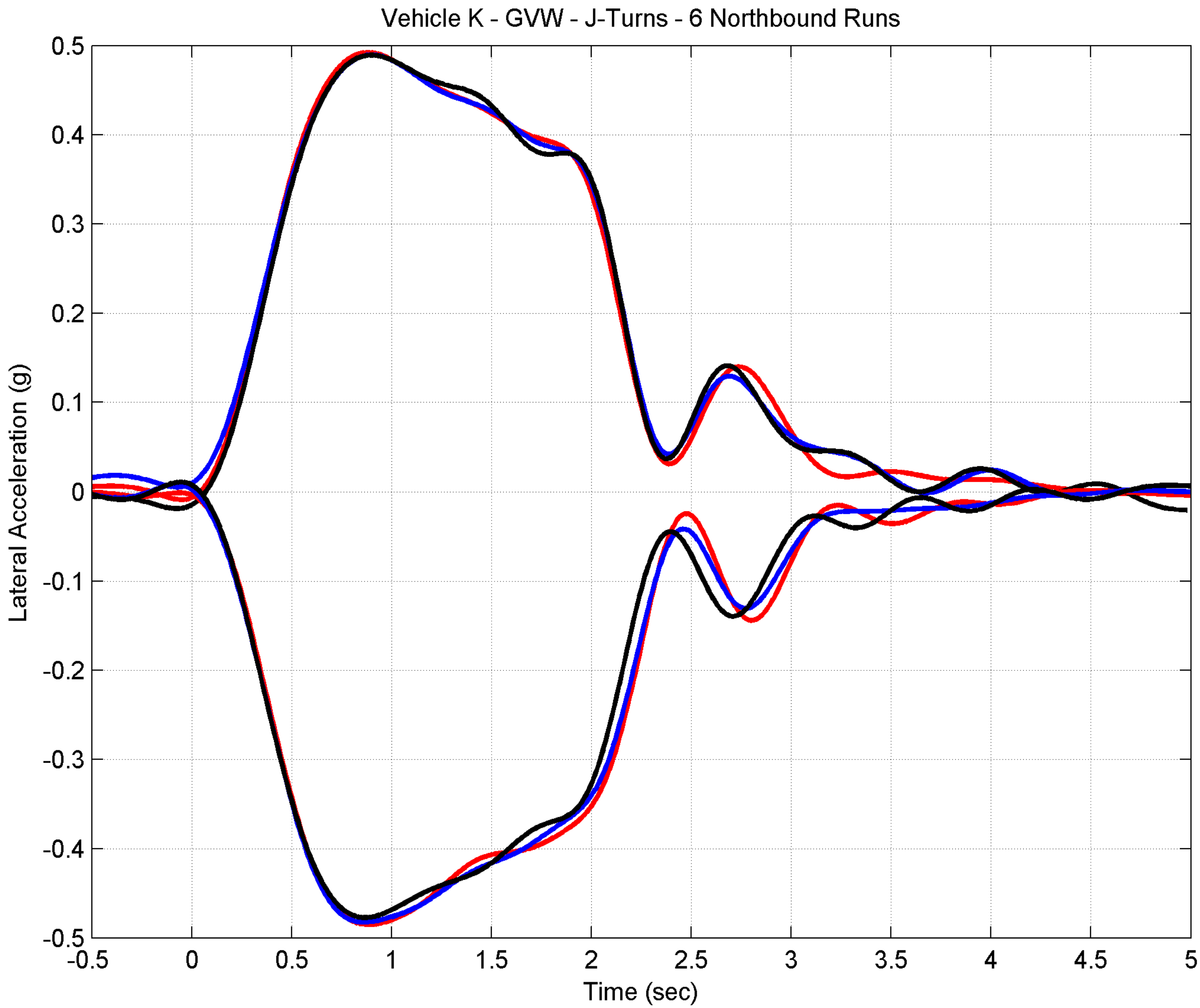

Vehicle K - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)


Vehicle K - GVW - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.23 g
CCW Transition to OS
At Ay = -0.225 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
14
12
10
8
6
4
2
0
-2
-4
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

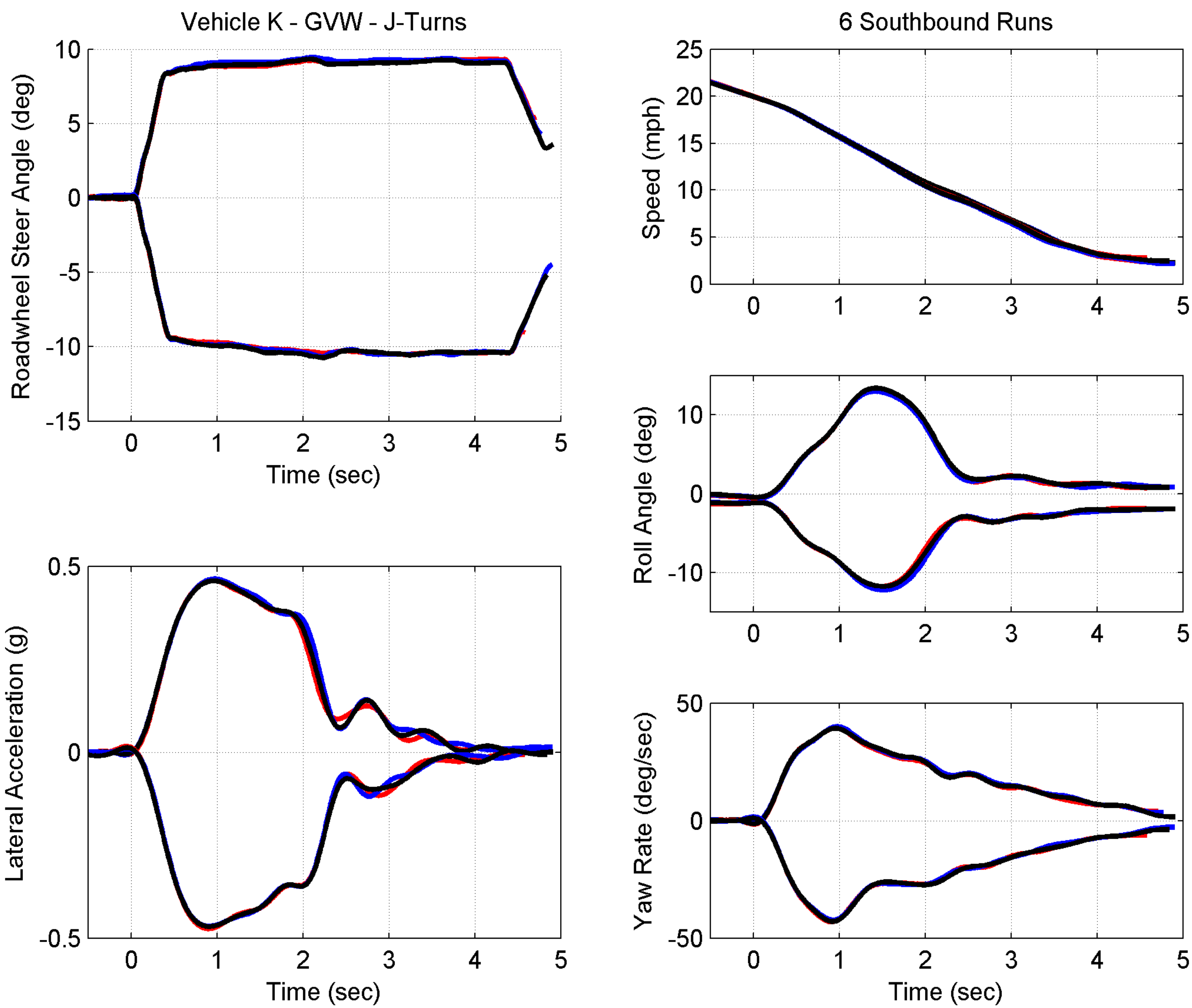


Vehicle K - GVW - 50 ft Radius Circle
10
8
6
4
2
0
-2
-4
-6
-8
-10
Roll Angle (deg)
Roll Gradient = -13.4 deg/g
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

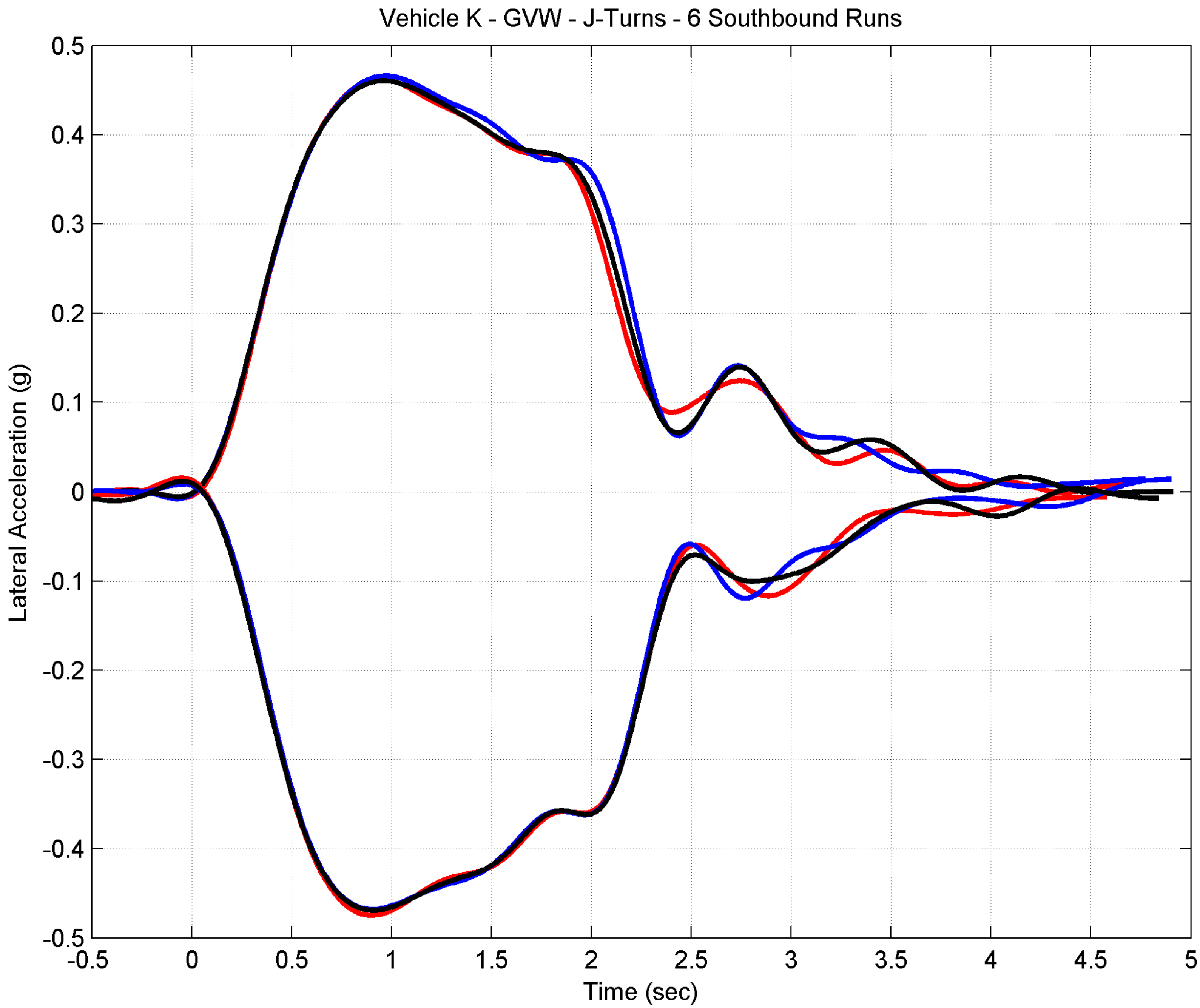

Vehicle K - GVW - J-Turns
6 Northbound Runs
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



Vehicle K - GVW - J-Turns - 6 Northbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)



Vehicle K - GVW - J-Turns
6 Southbound Runs
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle K - GVW - J-Turns - 6 Southbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle K - GVW

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

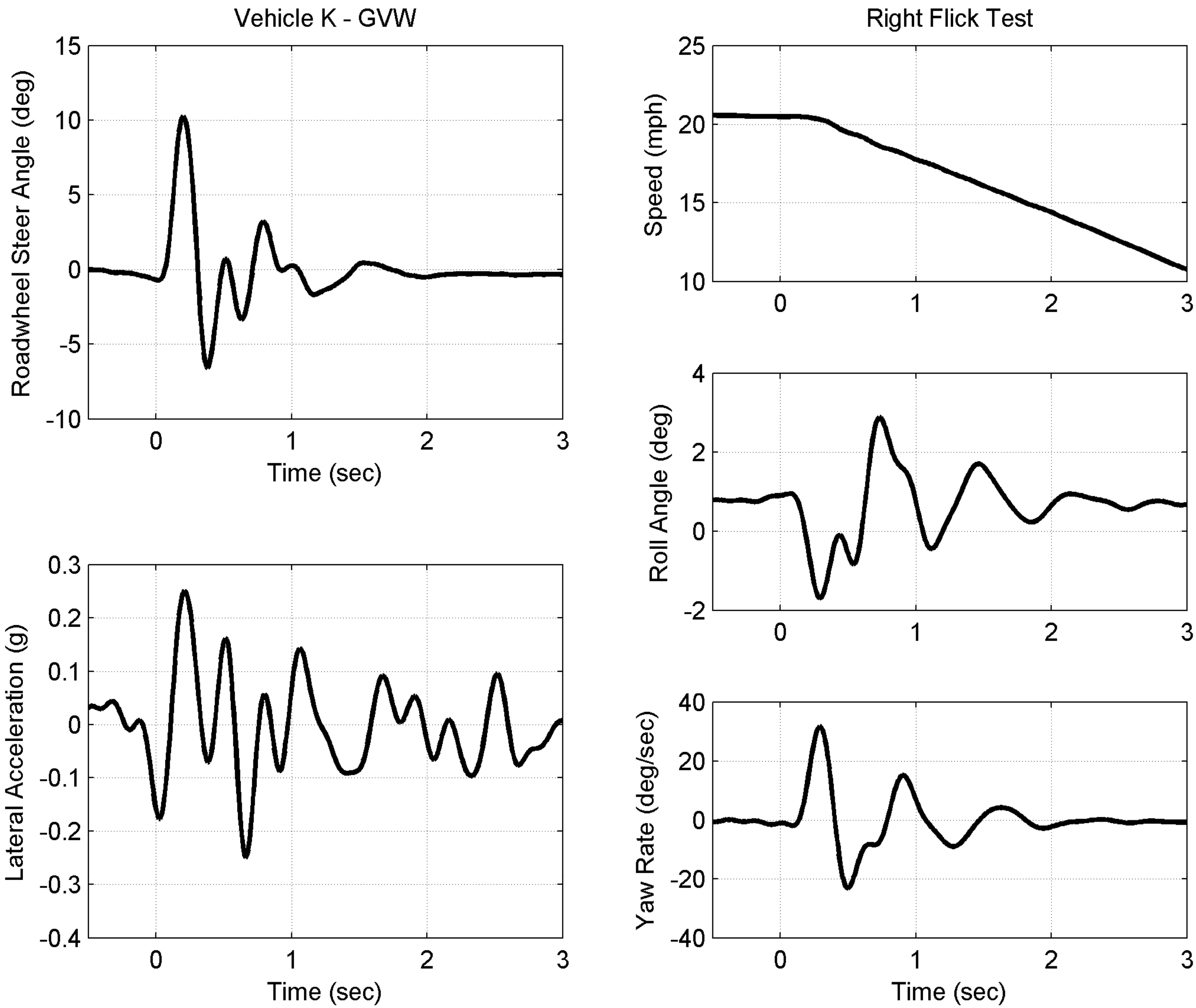
Run Number	Northbound Right Turns	Northbound Left Turns	Average of 6 Northbound Runs
1	0.4922	-0.4853	
2	0.4896	-0.4826	
3	0.4892	-0.4775	
Mean Value of 3 Runs	0.4903	-0.4818	**0.4861**
Standard Deviation of 3 Runs	0.002	0.004	

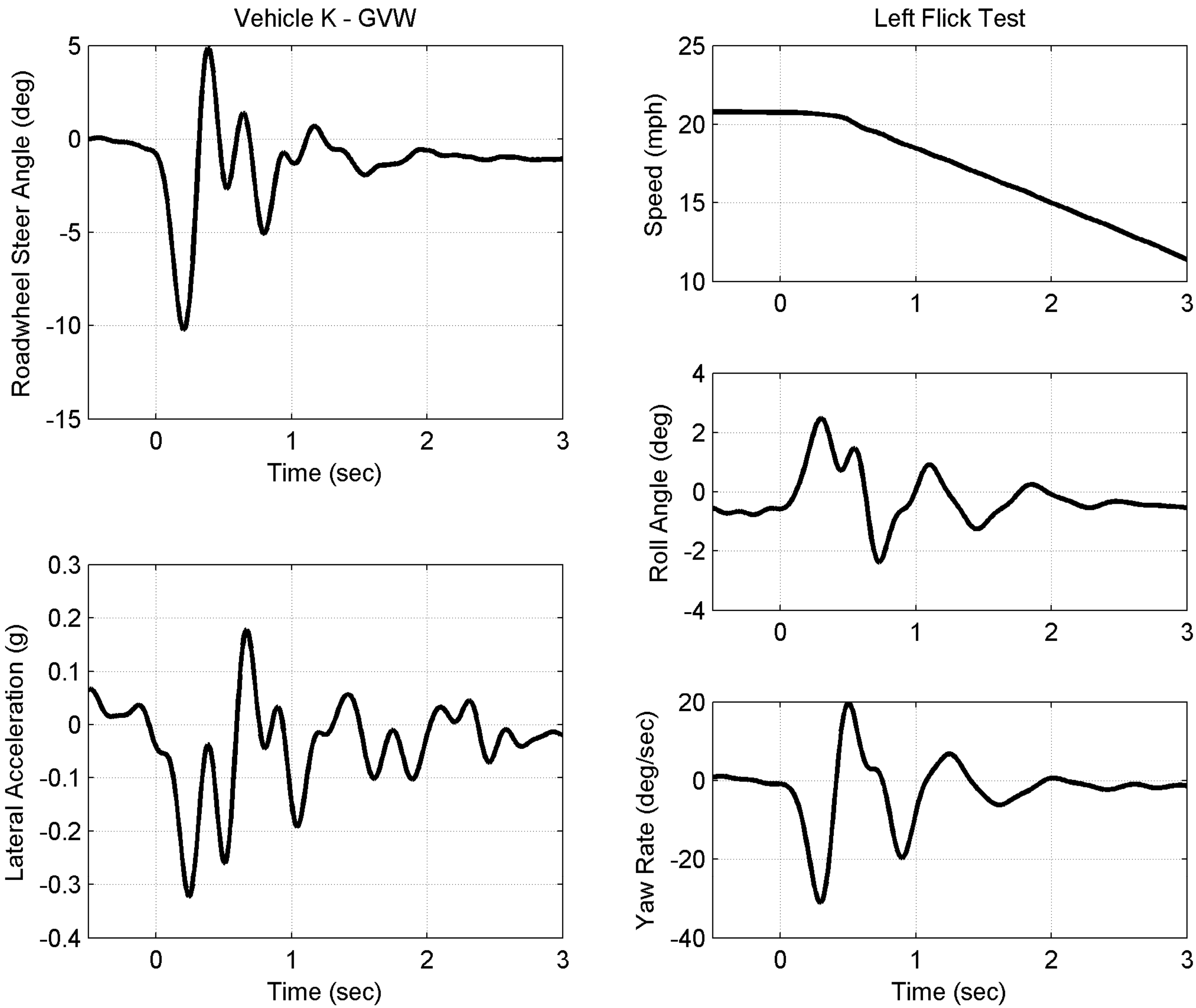
Average of All 12 Runs

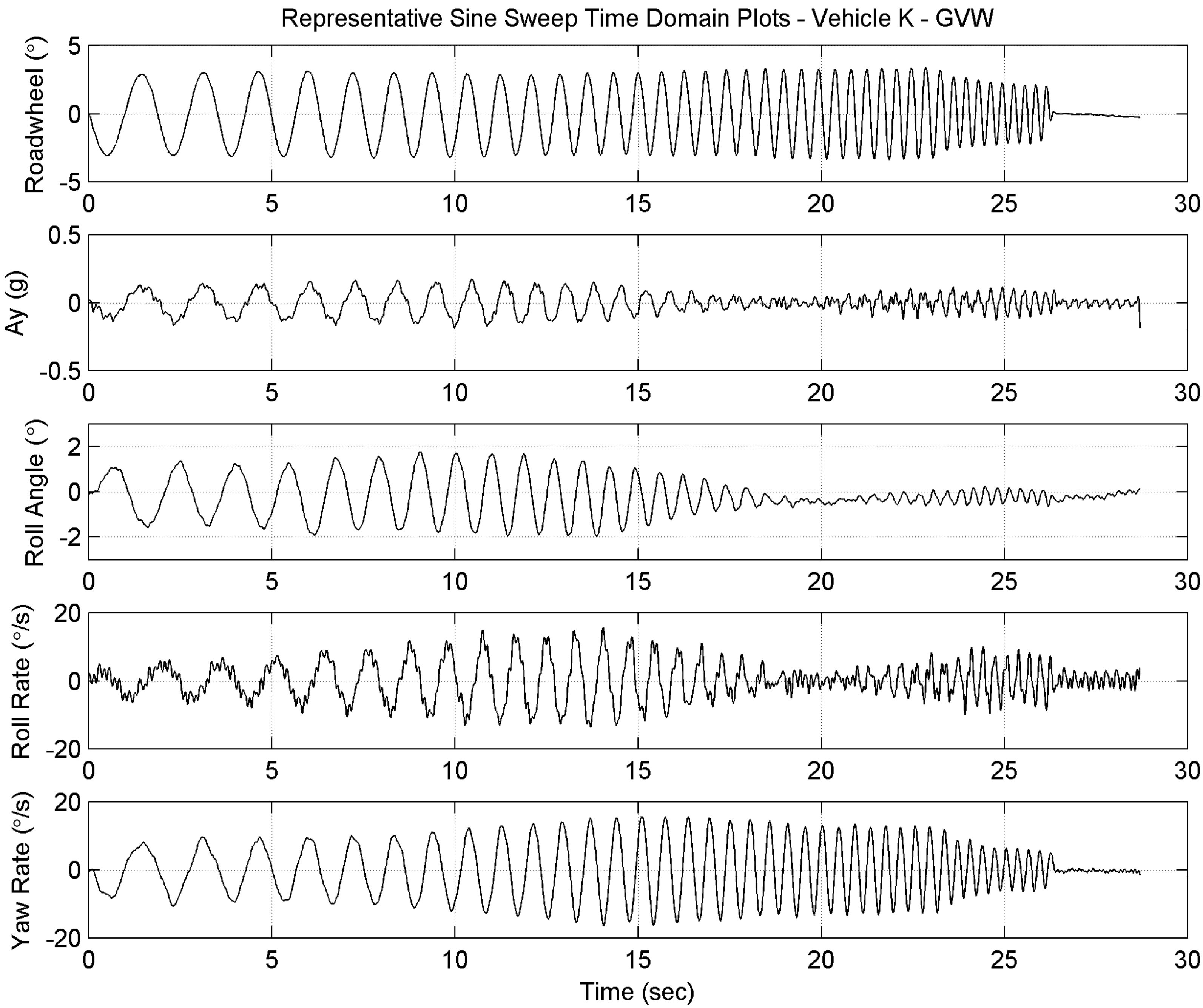
0.477

Threshold Ay

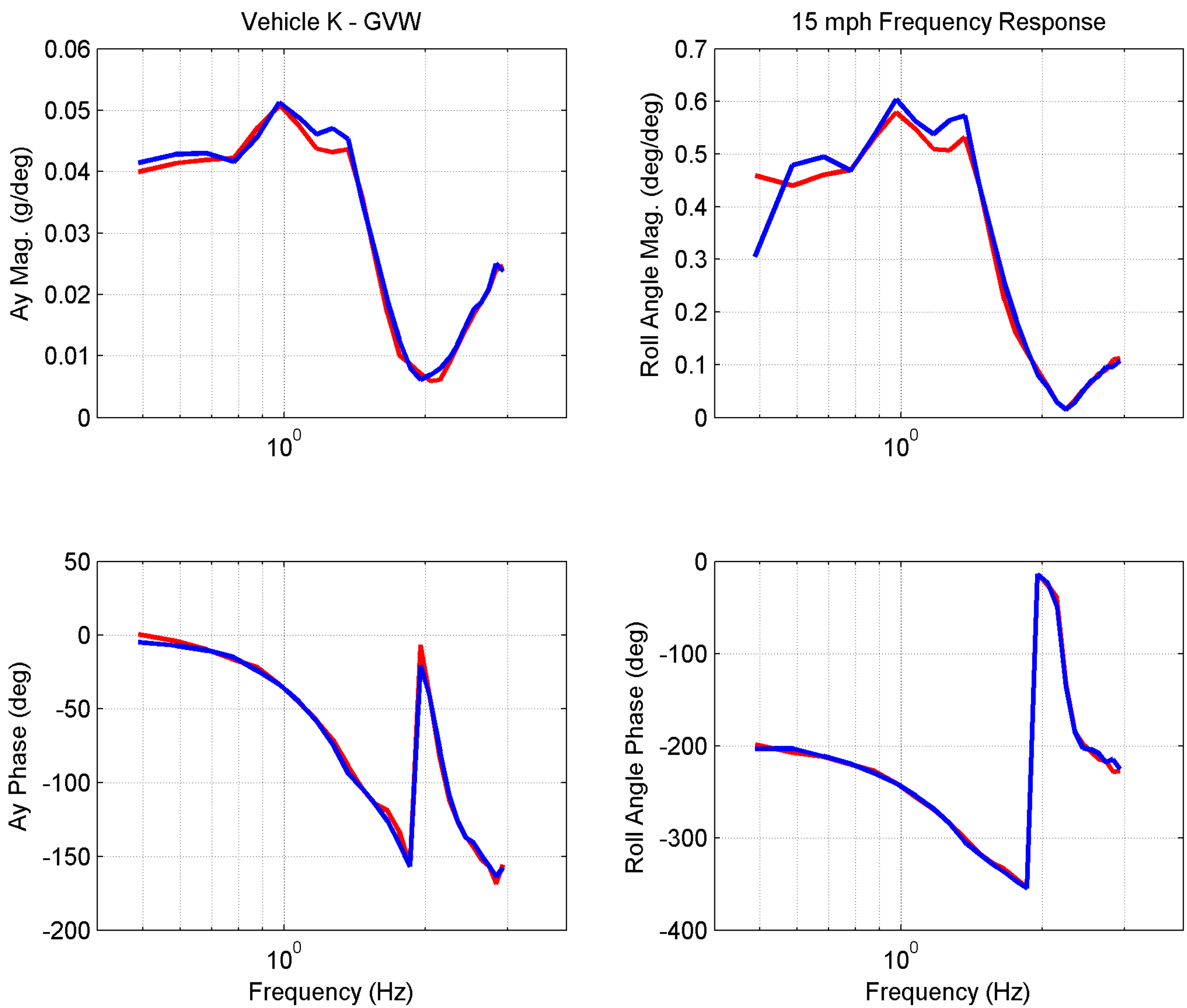
Run Number	Southbound Right Turns	Southbound Left Turns	Average of 6 Southbound Runs
1	0.4632	-0.4750	
2	0.4662	-0.4681	
3	0.4606	-0.4693	
Mean Value of 3 Runs	0.4633	-0.4708	**0.4671**
Standard Deviation of 3 Runs	0.003	0.004	

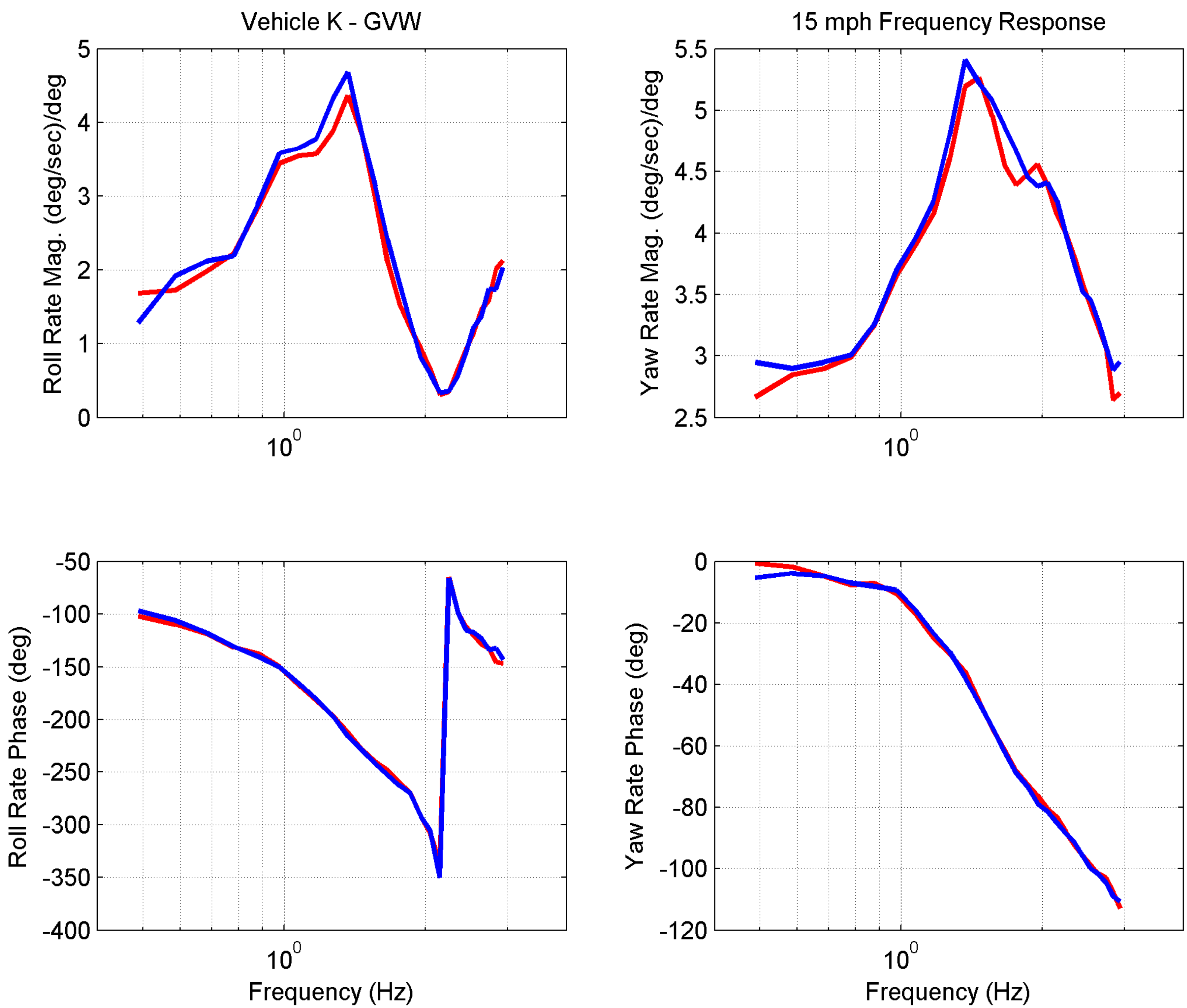

Vehicle K - GVW
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

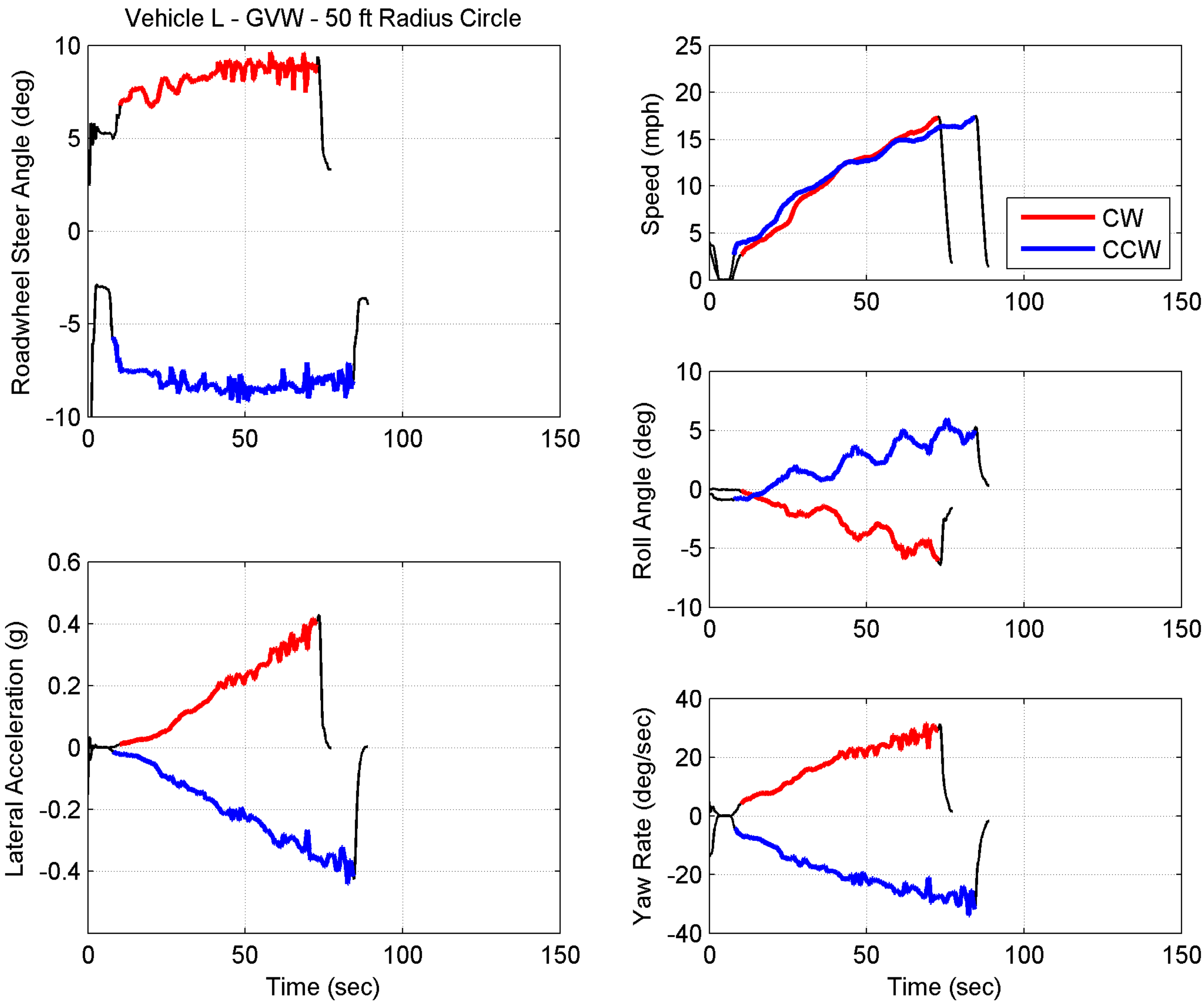

Vehicle K - GVW
Left Flick Test
Roadwheel Steer Angle (deg)
5
0
-5
-10
-15
Time (sec)
0
1
2
3
Speed (mph)
25
20
15
10
Roll Angle (deg)
4
2
0
-2
-4
Lateral Acceleration (g)
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Yaw Rate (deg/sec)
20
0
-20
-40

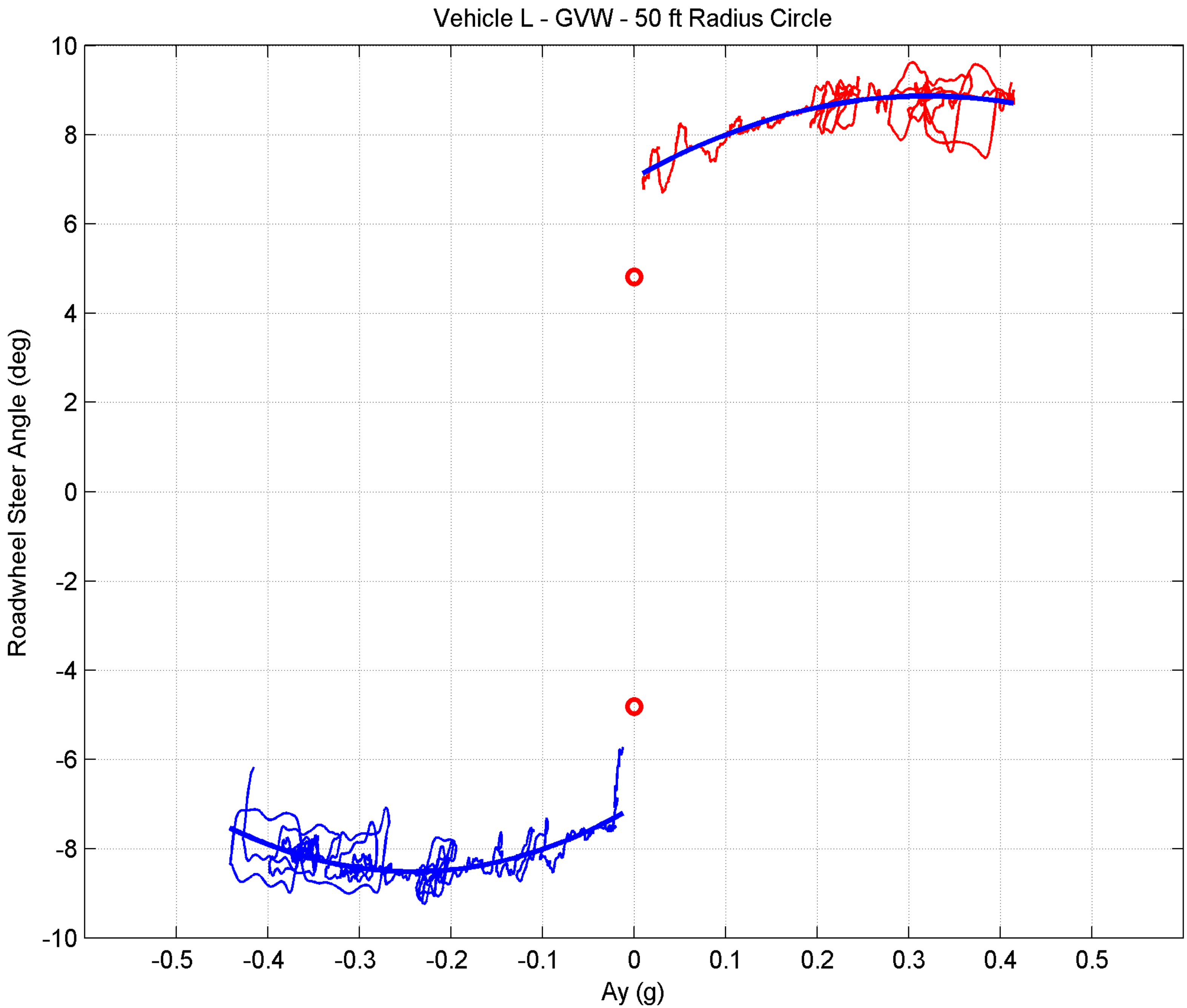


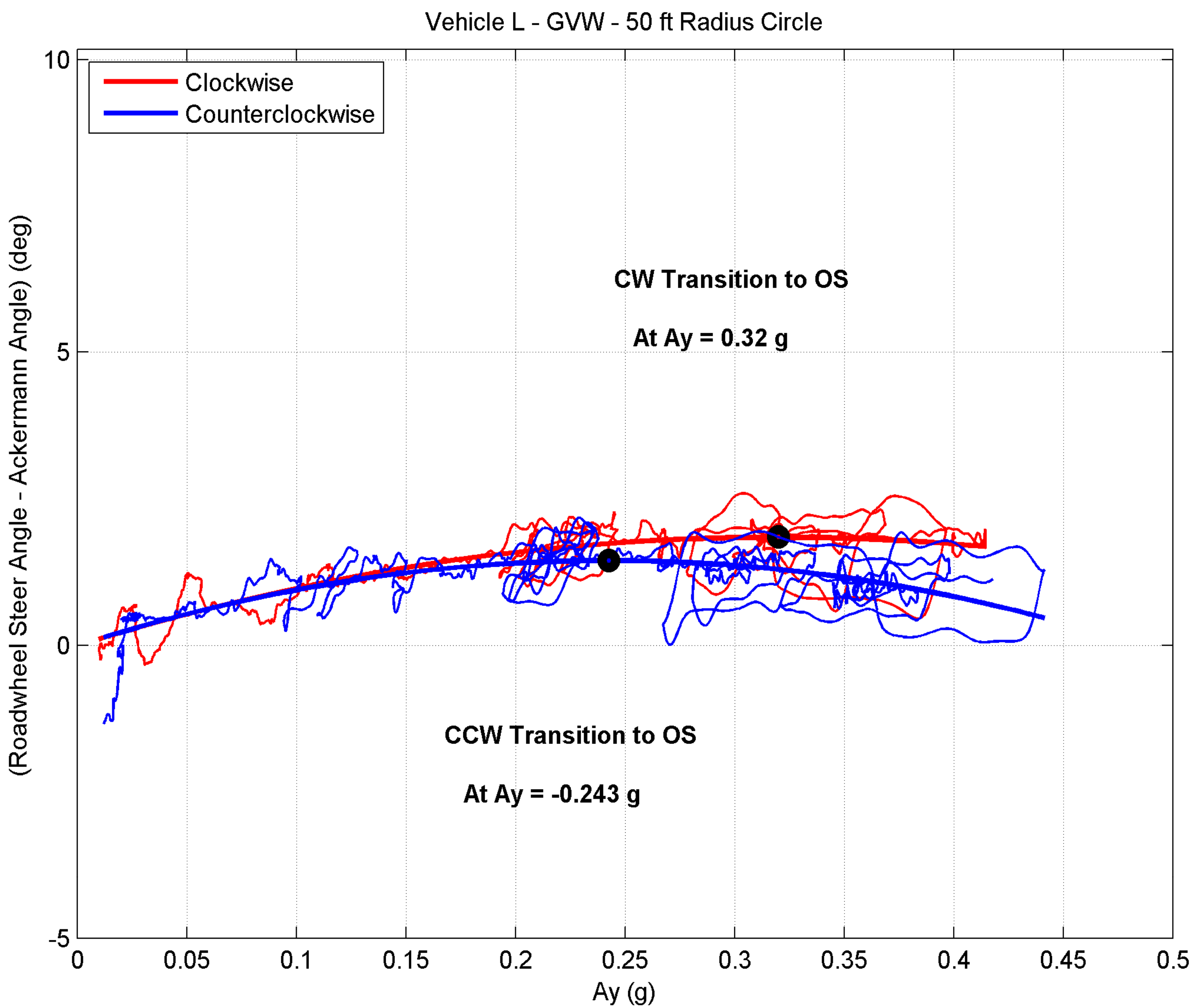
Representative Sine Sweep Time Domain Plots - Vehicle K - GVW
Roadwheel (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)


Vehicle K - GVW
15 mph Frequency Response
Ay Mag. (g/deg)
0.06
0.05
0.04
0.03
0.02
0.01
0
10^0
Roll Angle Mag. (deg/deg)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10^0
Ay Phase (deg)
50
0
-50
-100
-150
-200
10^0
Frequency (Hz)
Roll Angle Phase (deg)
0
-100
-200
-300
-400
10^0
Frequency (Hz)

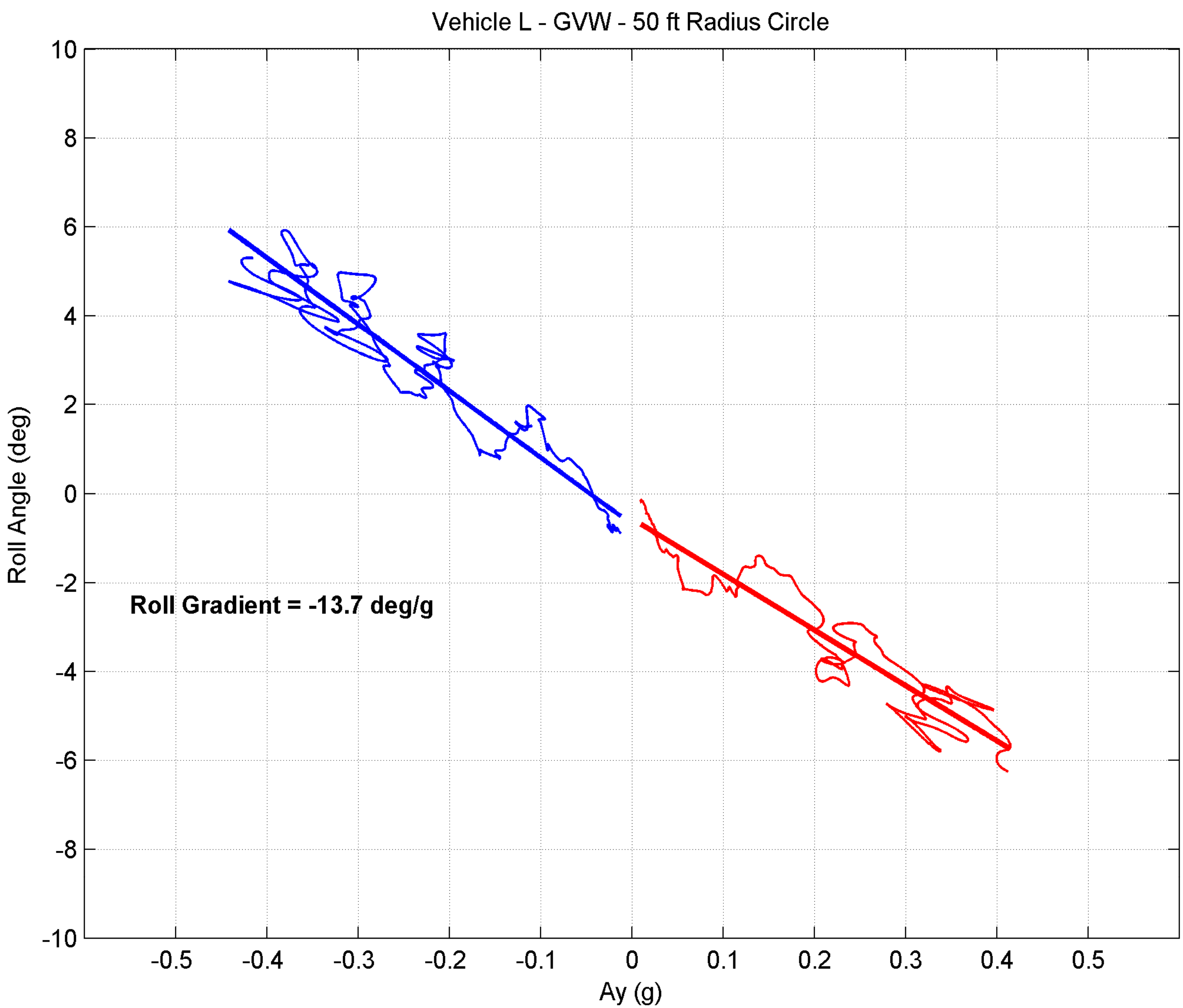

Vehicle K - GVW
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
5
4
3
2
1
0
5.5
5
4.5
4
3.5
3
2.5
-50
-100
-150
-200
-250
-300
-350
-400
0
-20
-40
-60
-80
-100
-120
10^0

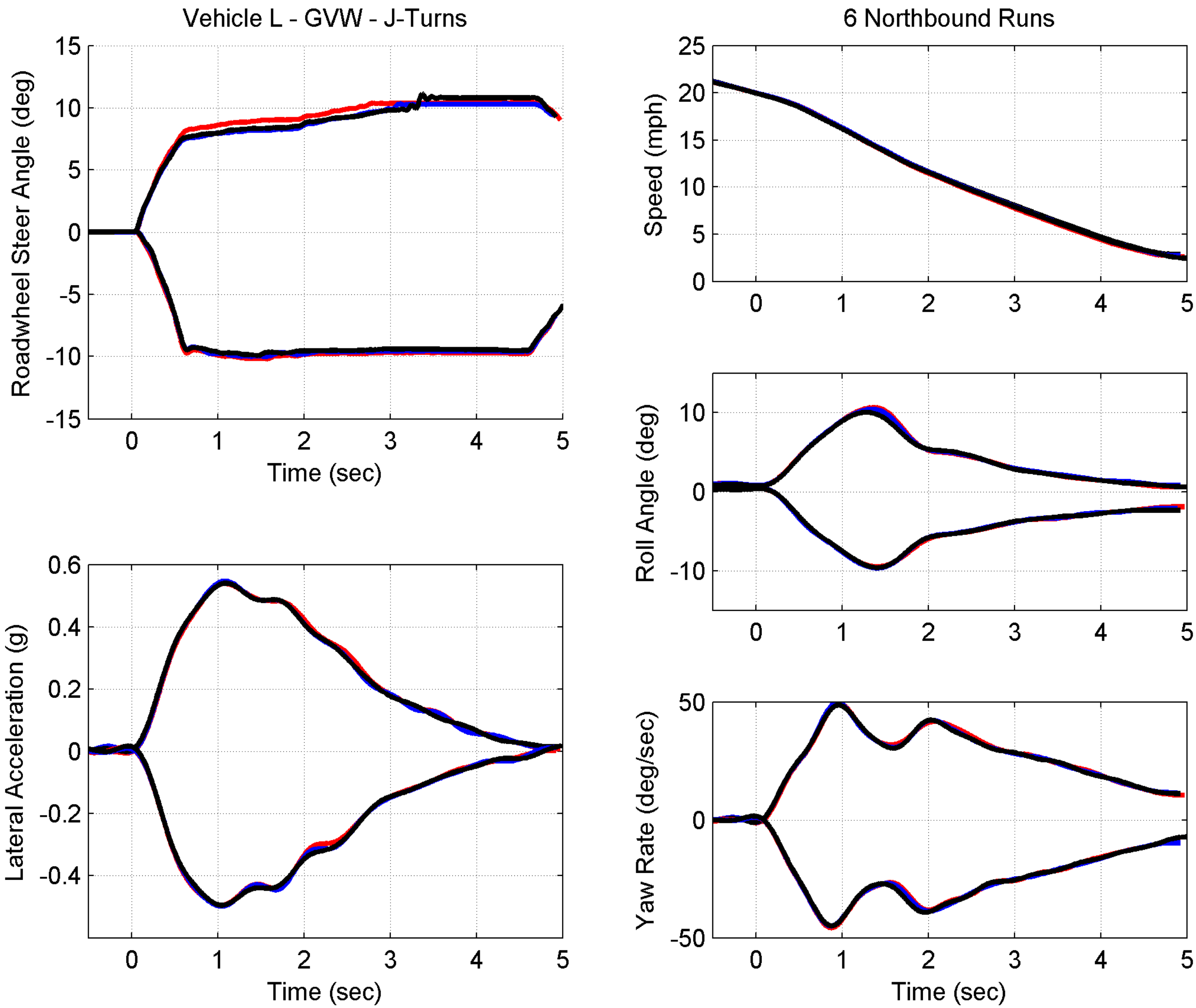

Vehicle L - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle L - GVW - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

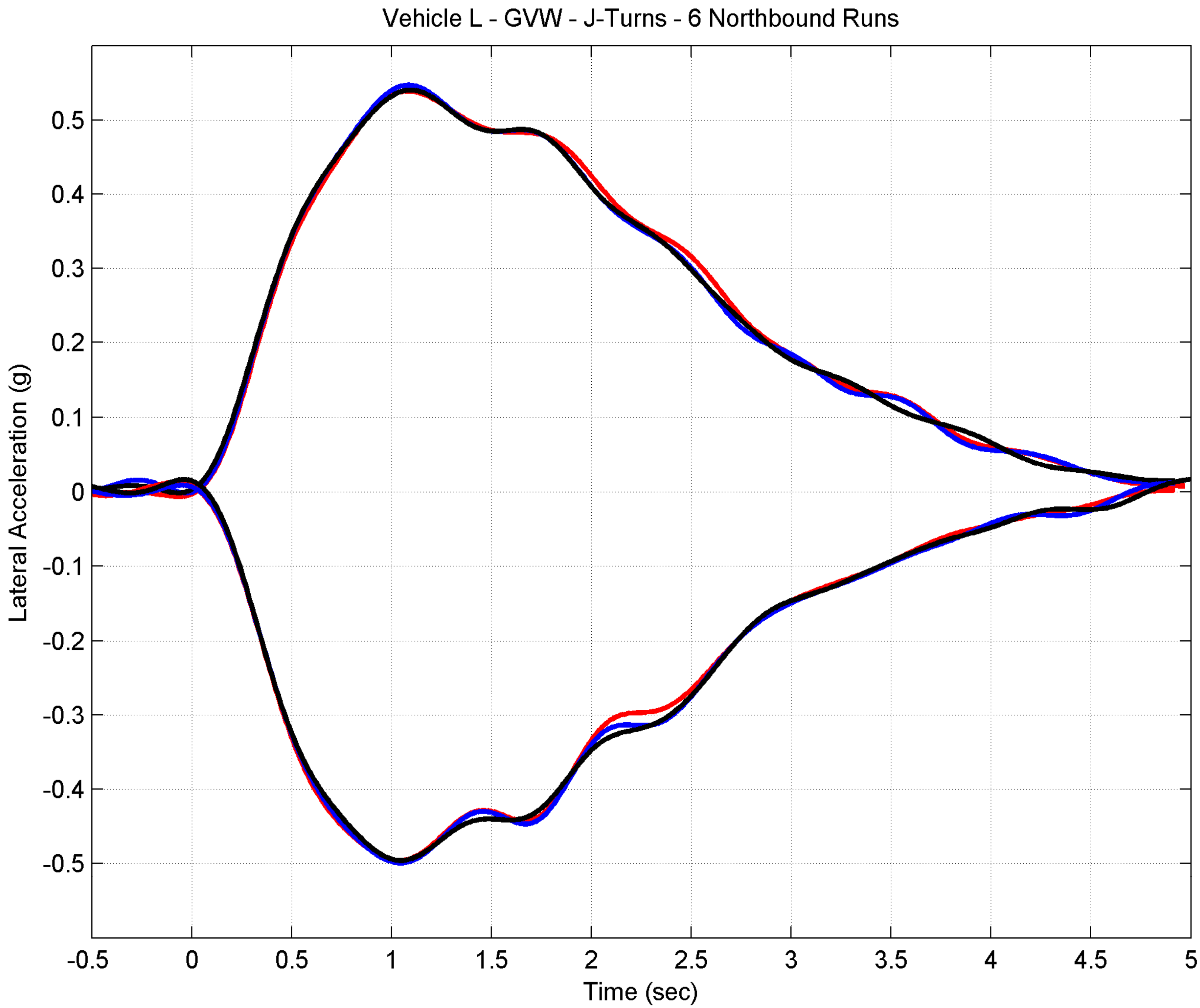


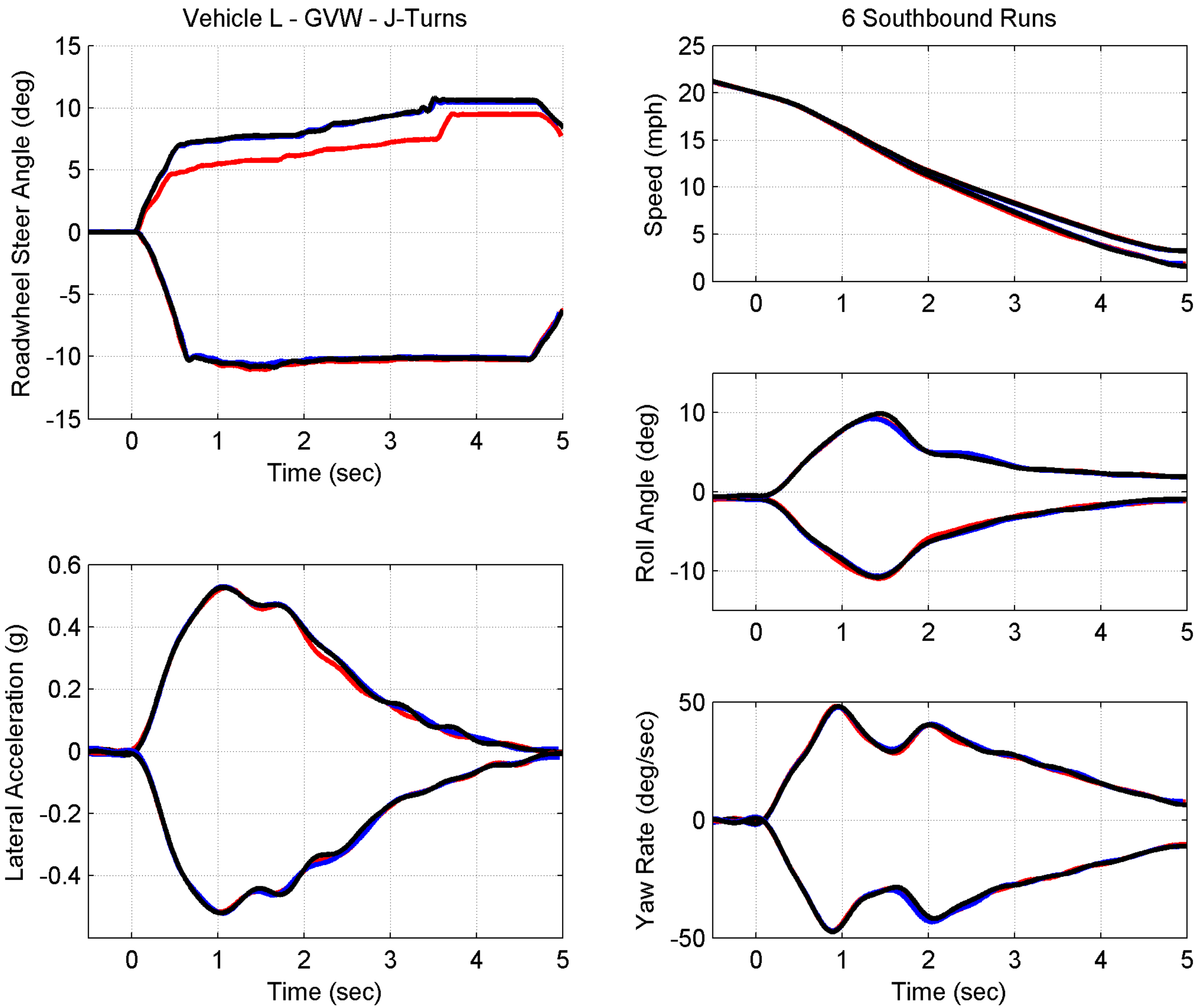
Vehicle L - GVW - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.32 g
CCW Transition to OS
At Ay = -0.243 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5


Vehicle L - GVW - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -13.7 deg/g
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

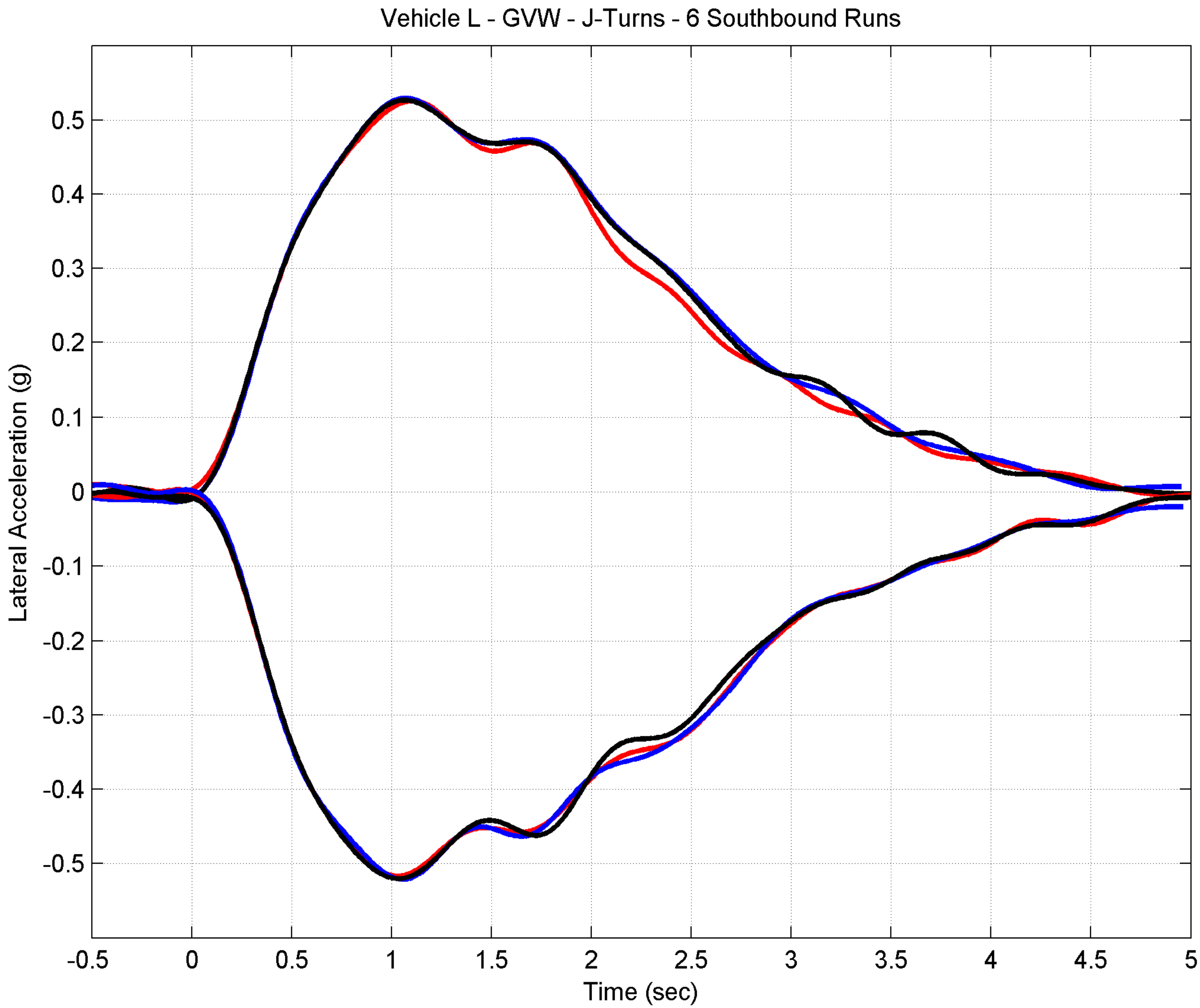


Vehicle L - GVW - J-Turns
6 Northbound Runs
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)
Speed (mph)
25
20
15
10
5
0
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Yaw Rate (deg/sec)
50
0
-50


Vehicle L - GVW - J-Turns - 6 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle L - GVW - J-Turns
6 Southbound Runs
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)
Speed (mph)
25
20
15
10
5
0
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
Yaw Rate (deg/sec)
50
0
-50



Vehicle L - GVW - J-Turns - 6 Southbound Runs
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle L - GVW

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

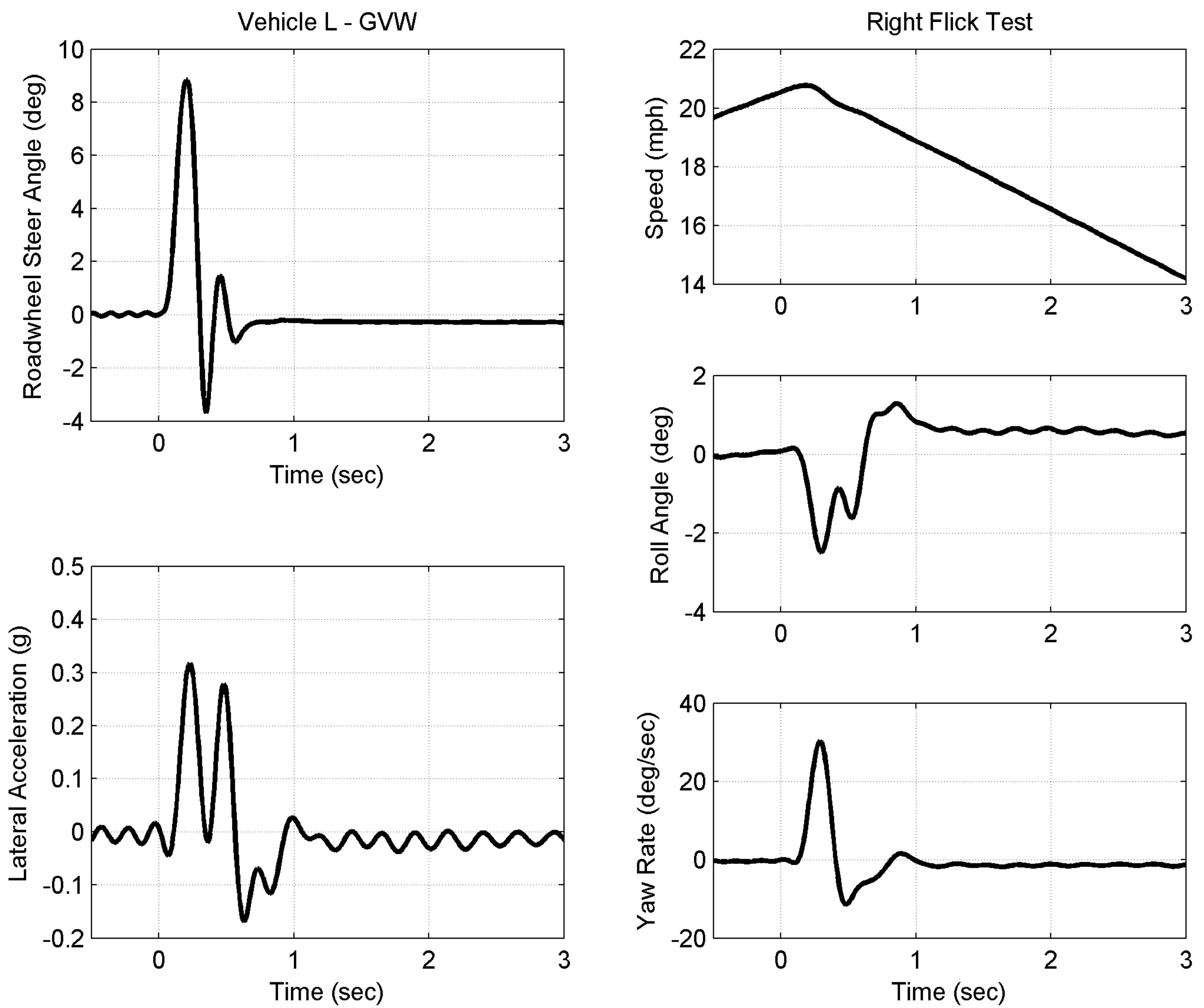
Run Number	Northbound Right Turns	Northbound Left Turns	Average of 6 Northbound Runs
1	0.5389	-0.4957	
2	0.5469	-0.4993	
3	0.5402	-0.4959	
Mean Value of 3 Runs	0.5420	-0.4970	**0.5195**
Standard Deviation of 3 Runs	0.004	0.002	

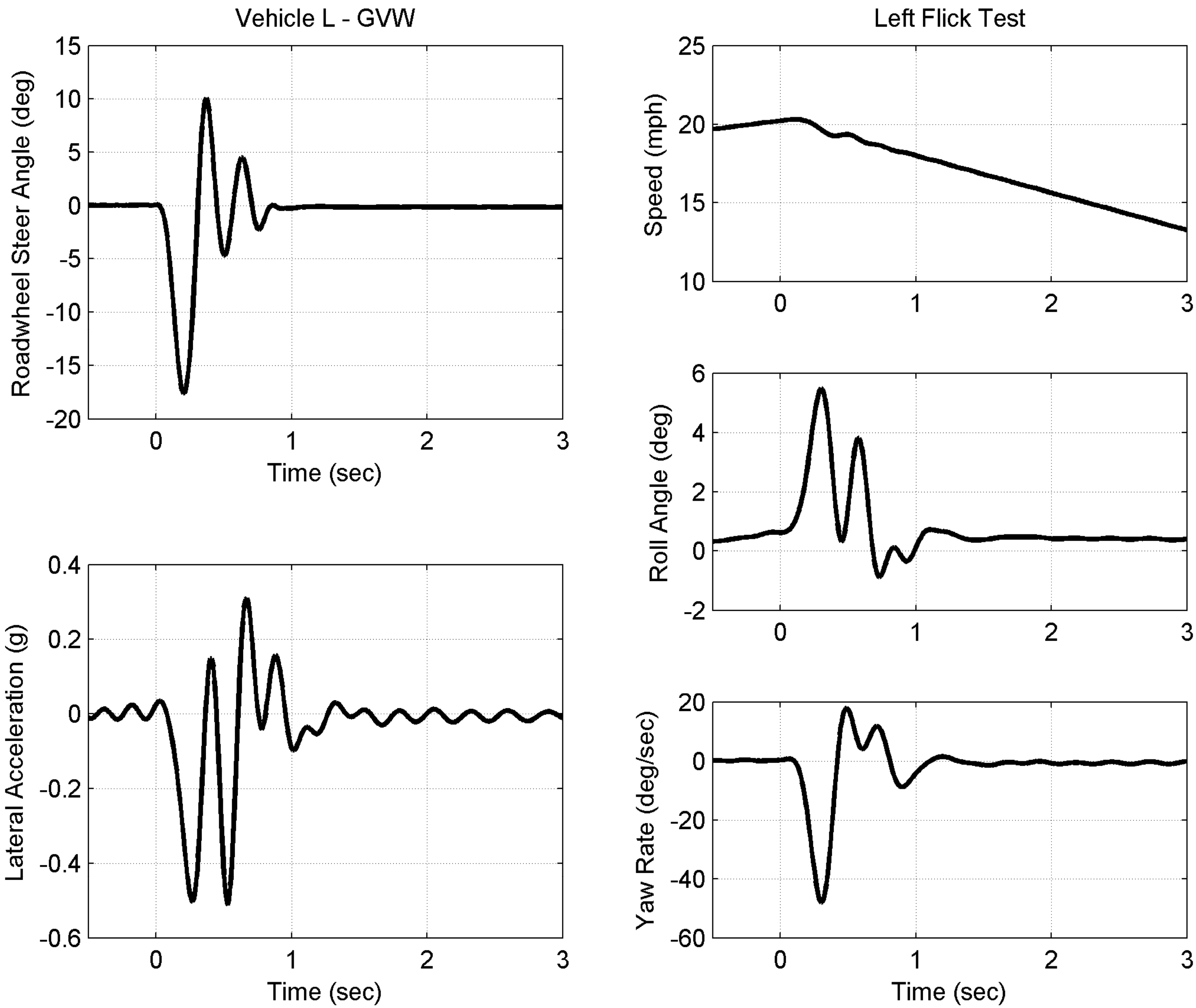
Run Number	Southbound Right Turns	Southbound Left Turns	Average of 6 Southbound Runs
1	0.5256	-0.5168	
2	0.5296	-0.5218	
3	0.5266	-0.5206	
Mean Value of 3 Runs	0.5272	-0.5197	**0.5235**
Standard Deviation of 3 Runs	0.002	0.003	

Average of All 12 Runs

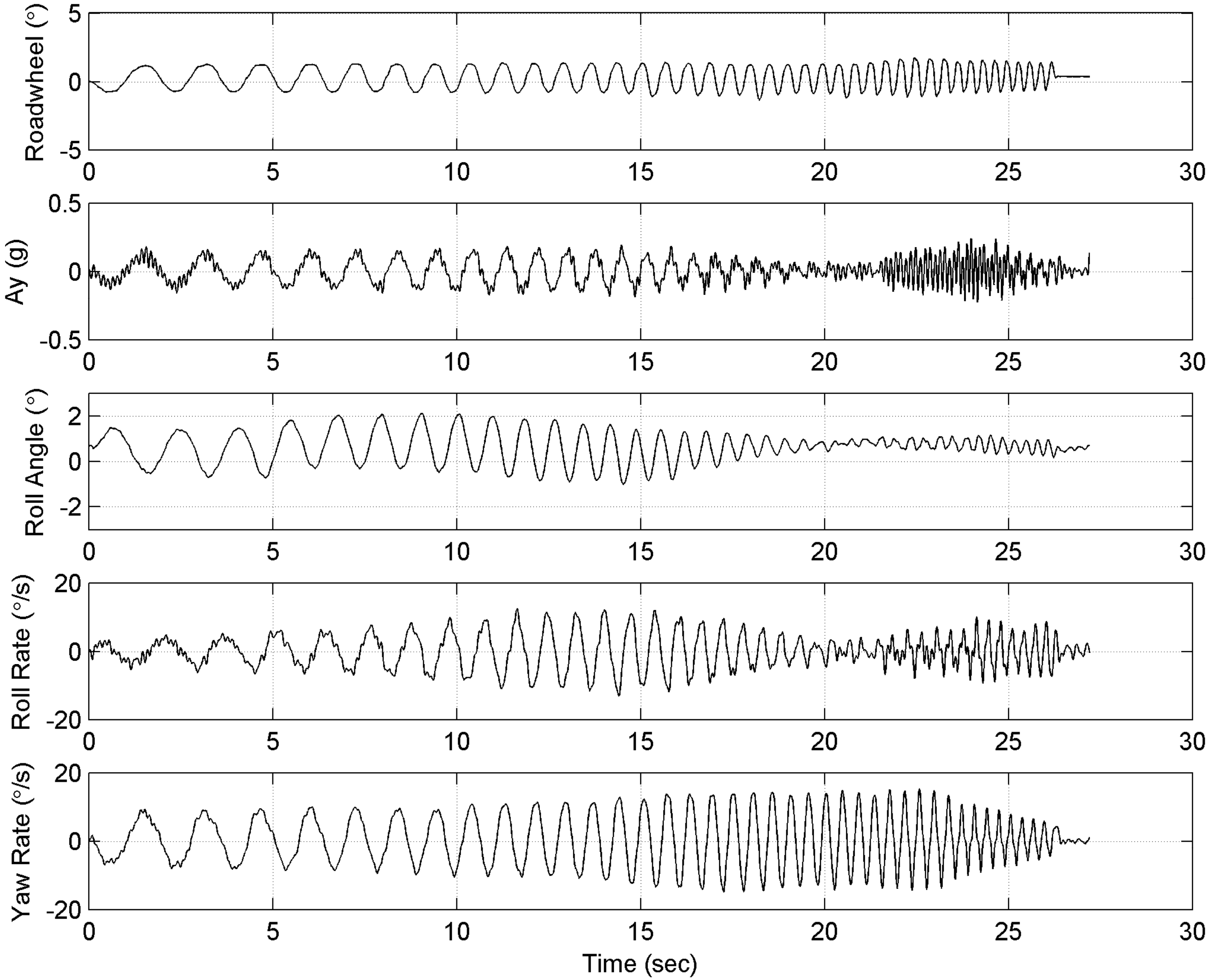
0.521

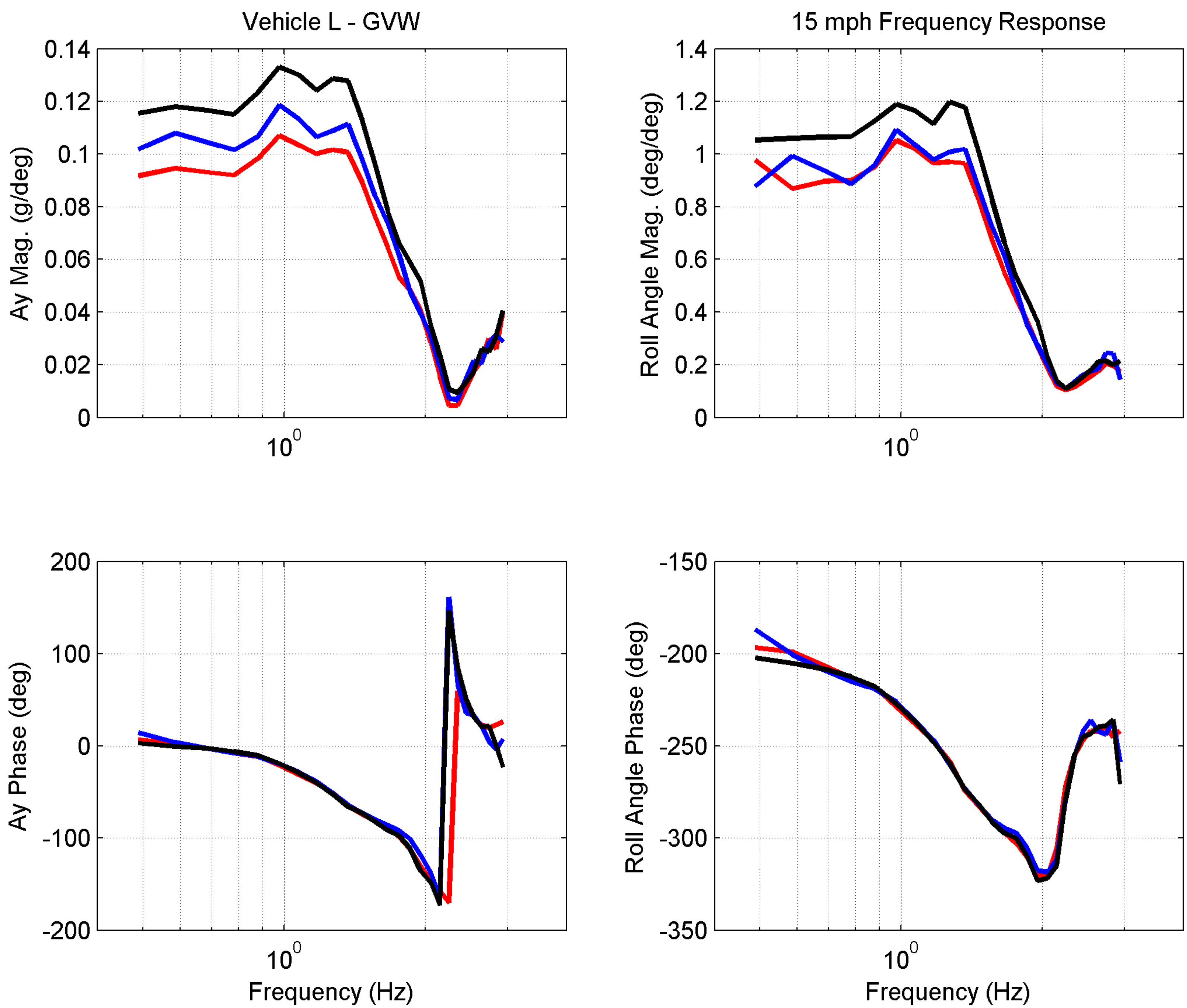
Threshold Ay

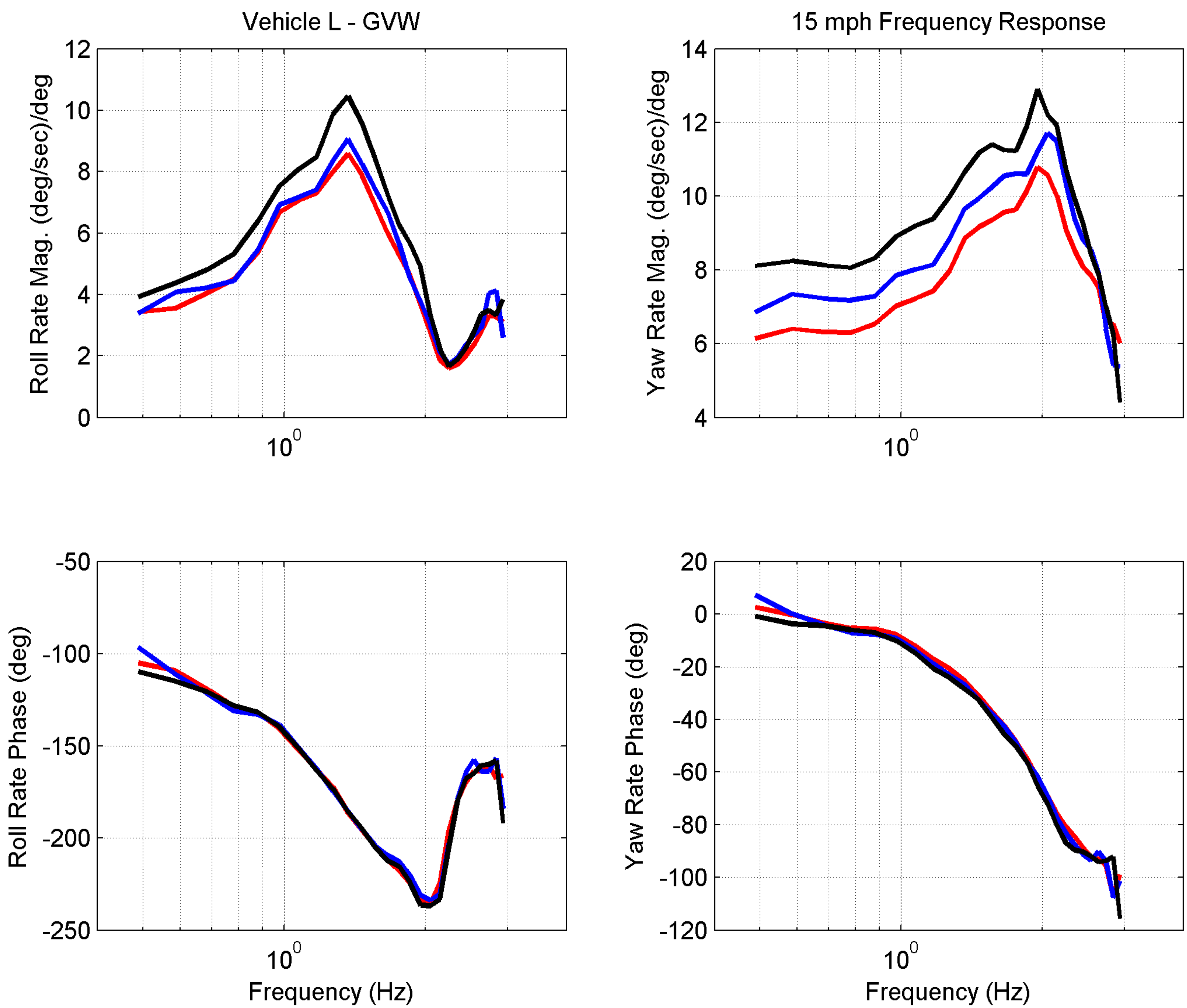

Vehicle L - GVW
Right Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle L - GVW
Left Flick Test
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

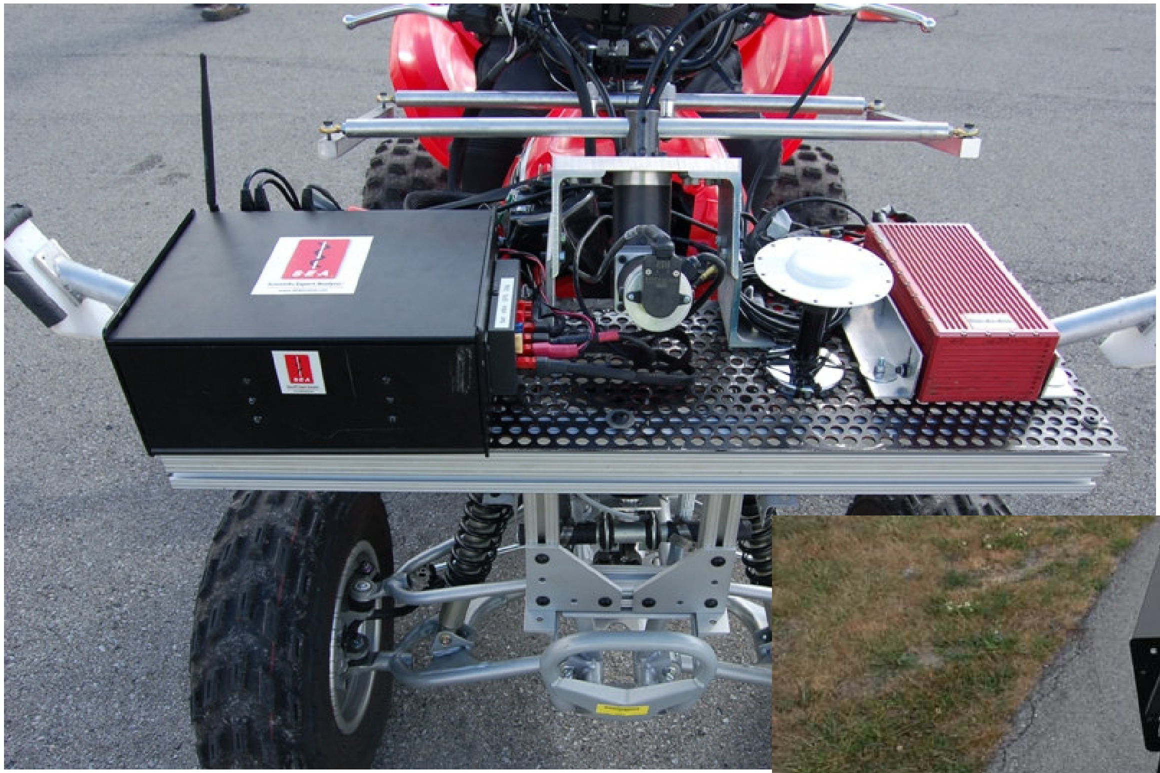
Representative Sine Sweep Time Domain Plots - Vehicle L - GVW

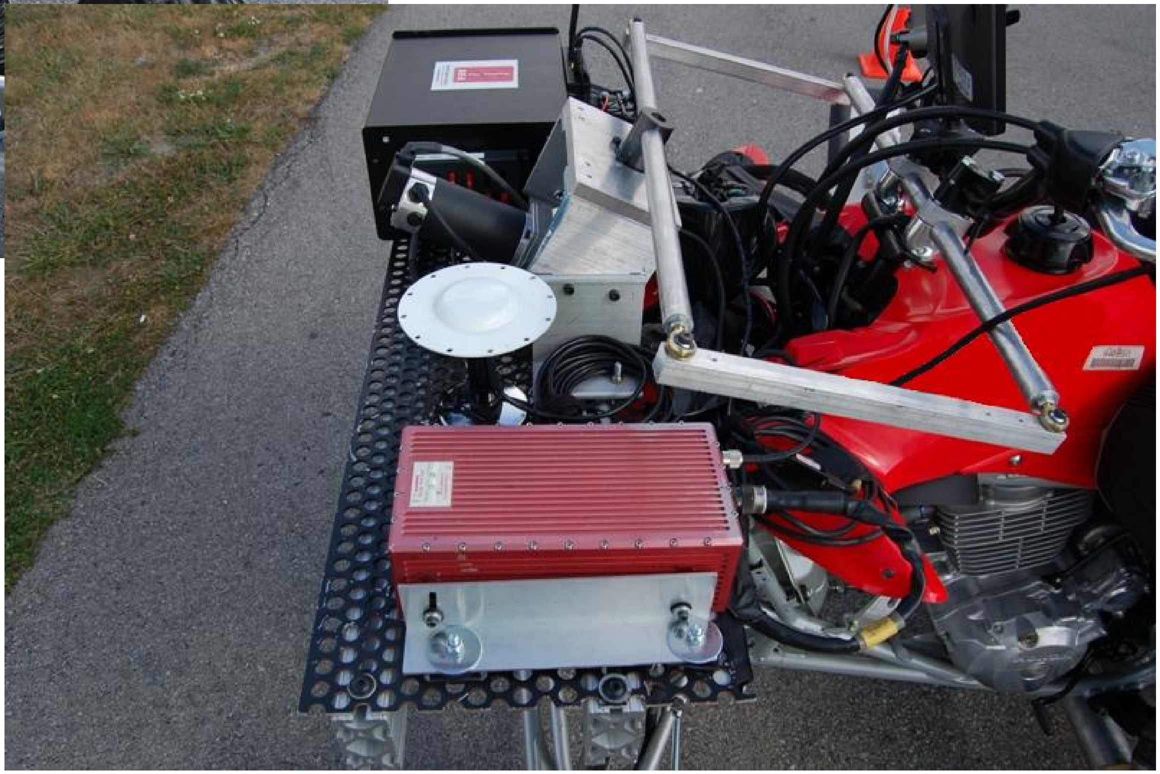



Vehicle L - GVW
15 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Frequency (Hz)
Frequency (Hz)


Vehicle L - GVW
15 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
10^0
0
2
4
6
8
10
12
14
-50
-100
-150
-200
-250
20
-20
-40
-60
-80
-100
-120

Photographs of SEA ATV Automated Steering Controller (ASC)





Photographs of SEA ATV Safety Outriggers

Photographs of GVW Loading

Photographs of SEA ATV Tilt Table

Photographs of Steering Column Angle Encoder