Bryansk State Technical University
Laboratory of Computational Mechanics

COMPARISON OF UNIVERSAL MECHANISM SOFTWARE AND OTHER MODELING PACKAGES FOR PERFORMANCE-BASED ASSESSMENTS OF HEAVY VEHICLES

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Title Comparison of Universal Mechanism software and other modeling packages for performance-based assessments of heavy vehicles

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Objectives To compare and determine if there acceptable agreement between simulations from computer-based models of heavy road vehicles created with Universal Mechanism software and other modeling packages.

Abstract The report named “Comparison of modeling systems for performance-based assessments of heavy vehicles” [1] was done by National road transport commission (NRTC) of Australia and put into public domain. That report includes results of numerical simulation of computer-based models of two heavy vehicles with the help of three separate computer-based modeling packages: *ADAMS*, *UMTRI’s constant velocity Yaw/Roll program* and *AUTOSIM*. The same input datasets were provided for each modeling package. Also, a review was performed of studies that have verified predictions from heavy vehicle simulations against test data.

In this report simulation results from Universal Mechanism software of the same two models of heavy vehicles are considered. It was done to prove that newly created program code provides good agreement with other well-known and trustworthy modeling packages.

Present report does not includes description of input dataset and manoeuvres, as well as plots of simulation outputs from ADAMS, UMTRI’s constant velocity Yaw/Roll program and AUTOSIM. All these data can be found in [1].

Links to download

The latest edition of this document is available here:
www.umlab.ru/download/40/manual/eng/umheavyvehicles.pdf

The latest release of UM 40 demo is available here:
http://www.umlab.ru/download/um40demo.exe

UM models of considered models are available here:
http://www.umlab.ru/download/40/bdouble.zip;
http://www.umlab.ru/download/40/trucktrailer.zip.

Original report by National road transport commission of Australia is available from the web site of NRTC at
http://www.ntc.gov.au/filemedia/Reports/ComparisonModellingSystemsPerfor.doc

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1. Universal Mechanism

Universal Mechanism (UM)[1] was developed in the 1990s at the Laboratory of Computational Mechanics of Bryansk State Technical University, Russia. Universal Mechanism like typical multi-body program takes as input rigid and elastic bodies interconnected with the help of joints and force elements. UM has built-in module for simulation of road vehicle dynamics. As a universal tool UM gives a user a possibility to choose any level of details in his/her computer models.

Universal Mechanism automatically generates equations of motion and then numerically solves these equations. Online animation of motion and plots of dynamical performances are available during simulation. There are lots of measurable dynamical performances of mechanical systems: linear and angular coordinates, velocities and accelerations, active forces and moments, reaction forces etc.

[1] More information about Universal Mechanism you can find at www.umlab.ru

2. INPUT DATA SET AND MANOEUVRES

Two models of heavy vehicles are considered in this report: B-double and truck/trailer.

The model of B-double consists of 3 subsystems (prime mover, trailer 1 and trailer 2), 48 rigid bodies, 51 joints and 27 forces of different types. The model of truck/trailer includes 2 subsystems (truck and trailer), 33 rigid bodies, 36 joints and 18 force elements.

Each vehicle was tested with four manoeuvres. Two of them are open-loop manoeuvres: pulse steer and step steer. The rest two are closed-loop manoeuvres: SAE lane change and low-speed 90º turn.

All parameters of vehicles (mass properties, couplings, springs and dampers, properties of tyres, ect.) and manoeuvres are set strictly according to [1].

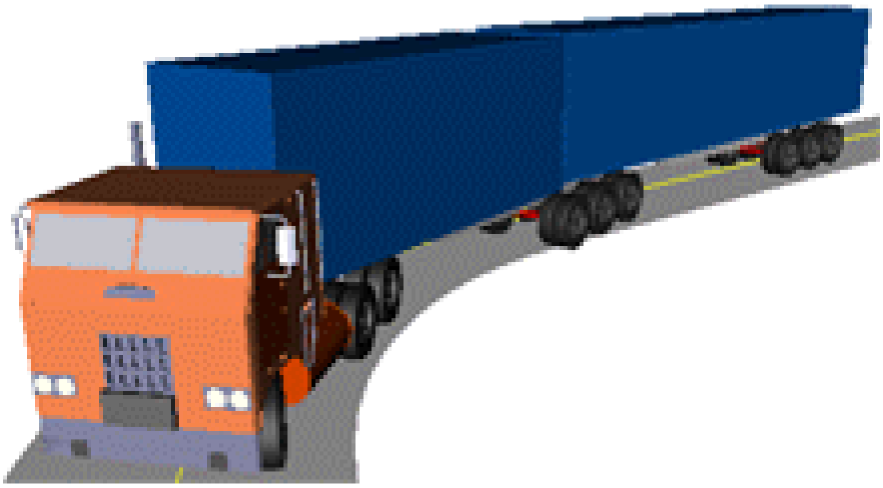

Figure 2.1. Universal Mechanism model of reference B-double

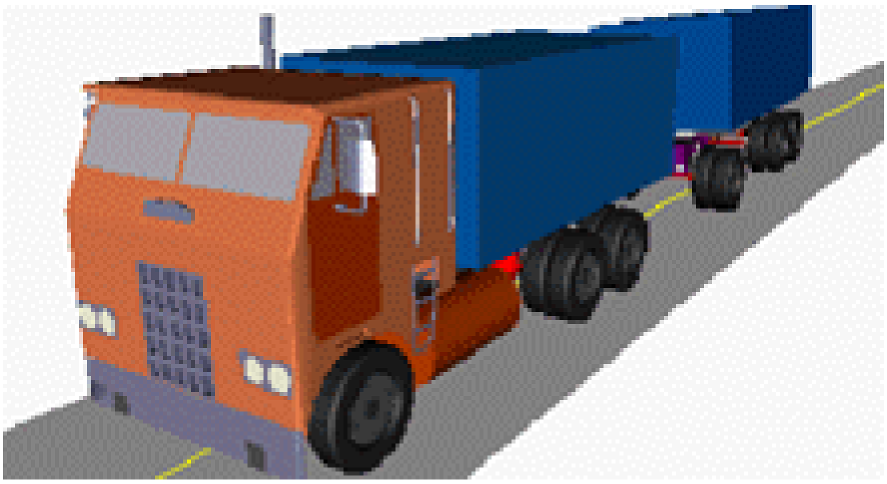

Figure 2.2. Universal Mechanism model of reference truck/trailer

3. COMPARISON OF SIMULATION RESPONSES

Simulation results for both vehicles in all manoeuvres are collected in the section 5. PLOTS OF SIMULATION OUTPUTS.

These plots show that there is quite close agreement of outputs from Universal Mechanism and other three modeling packages. Reasons of some deviation of results are discussed in [1].

All plots from Universal Mechanism in sect. 5 can be compared with results of other modeling packages, that can be found in appendix D of [1]. Output plots in sect. 5 and in [1] has the same sequence in order to make the comparison easier.

4. Simulation in Universal Mechanism

Models of B-double and truck/trailer for UM 4.0 can be downloaded using the following links:

http://www.umlab.ru/download/40/bdouble.zip;

http://www.umlab.ru/download/40/trucktrailer.zip.

Once downloaded the UM 40 demo version[1] and these models of heavy vehicles you can go through all the manoeuvres from this report and obtain the results by yourself. This section will show you how to do it.

1. Download and install UM 4.0.
2. Download models of vehicles using above links.
3. To have a look what the models consist of run **UM Input** program and open models there.

Note a) Models are created according to the report of National road transport commission of Australia, where all input data and manoeuvres. The report is available here:
http://www.ntc.gov.au/filemedia/Reports/ComparisonModellingSystemsPerfor.doc

b) Using demo version you will not be able to generate equations of motion of the models. So, if you use demo version of UM do not save and regenerate equations of motion, otherwise old DLL of the model will be deleted and new one will not be created.

4. To start numerical simulation of the models run **UM Simulation** program.
5. Open the **bdouble** model (**File/Open** menu command).

[1] http://www.umlab.ru/download/um40demo.exe

6. Select **pulsesteer** from the **File/Load configuration** menu command.

Note Both models have four preset configurations:

- **pulsesteer** (pulse steer, open-loop manoeuvre)**;**
- **stepsteer** (step steer, open-loop manoeuvre)**;**
- **SAE lane change** (closed-loop manoeuvre)**;**
- **lowspeed90turn** (low speed 90º turn, closed-loop manoeuvre)**.**

Configurations differ from each other arranging animation and graphical windows, value of vehicle velocity and selected test for a vehicle.

After loading a configuration file several graphical windows appear. Every window will online plot some of performances that are given in the sect. 5 and in the report [1]. Configurations include only a part of all plots that are given for each model. All variables are collected in the **List of Variable** (**Tools/List of variables** menu item) of the same name - **bdouble.var** and **trucktrailer.var** correspondently.

7. Select the **Analysis/Simulation** menu item. **Object simulation inspector** appears.
8. Click the **Identifiers** tab to check out the velocity that is set for current manoeuvre (**v0** identifier). You need not change any parameters; just have a look which parameters will be used during numerical simulation.

9. Click the **Road vehicle/Tests** tab to check out the current manoeuvre.

Note

Open loop steering (*pulse steer, step steer***)**
Select the **Road vehicle/Tests** tab in the **Object simulation inspector** and in the **Steer angle plot** click . For example, Fig. 4.1 shows open loop steering for the *pulse steer* test.

Closed loop steering (*SAE lane change, low speed 90º turn***)**
Select the **Road vehicle/Tests** tab in the **Object simulation inspector** and in the **Macro geometry file** click . For example, Fig. 4.2 shows the target path for the vehicle for the *SAE lane change*.

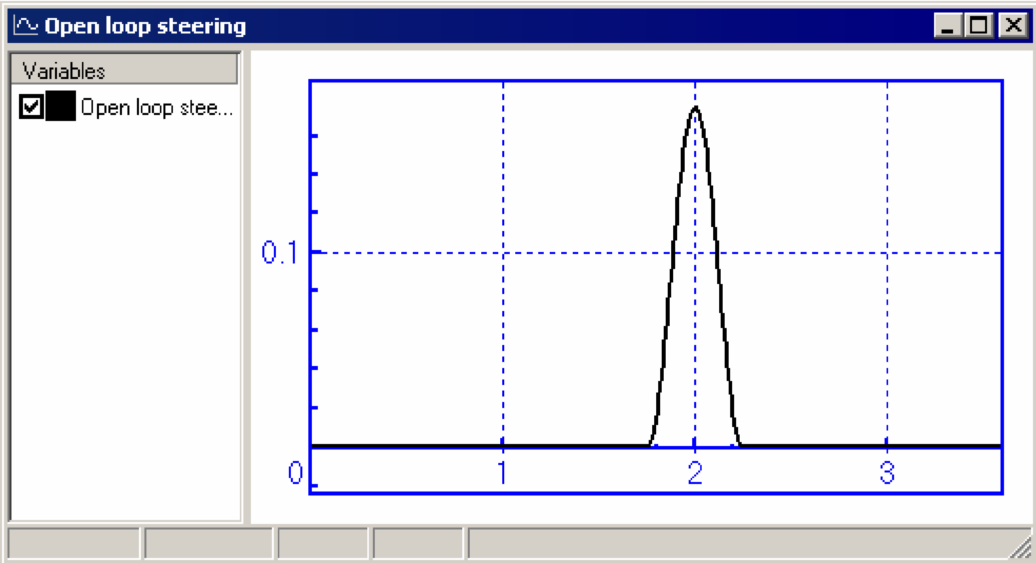

Figure 4.1. Steering angle for the *pulse steer* test

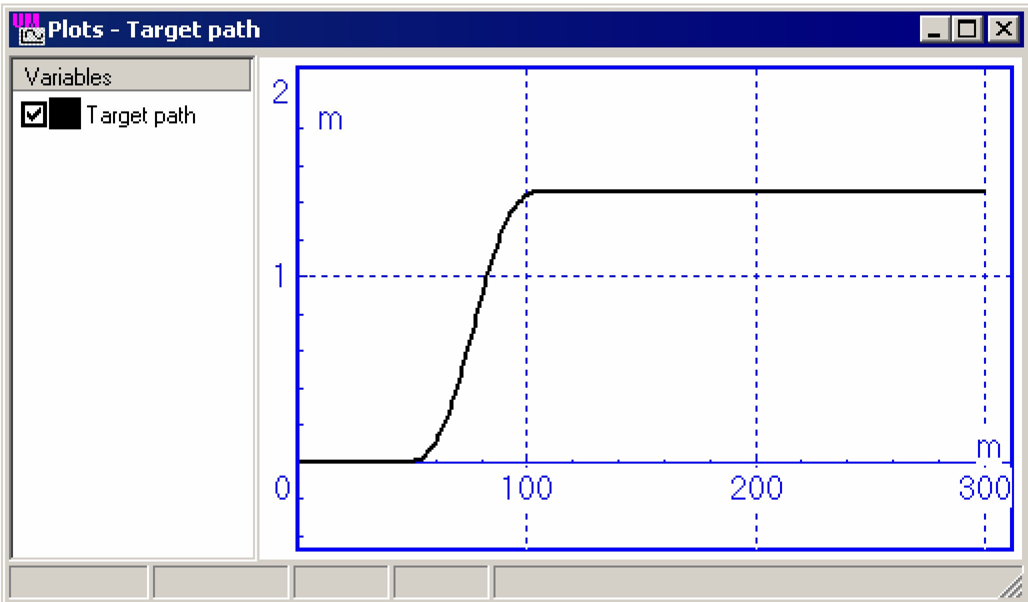

Figure 4.2. Target path for the *SAE lane change*

10. Click the **Integration** button to start numerical simulation.

Now you can see some plots in graphical windows. You can compare these plots with plots from other modeling packages for simulation of road vehicle dynamics, see Appendix D of [1].

11. Sequentially load other configurations for **bdouble** model (**File/Load configuration** menu command): **stepsteer**, **SAE lane change**, **lowspeed90turn** and start numerical simulation like it is shown above.
12. Load the **trucktrailer** model and go through steps 5-9.

5. PLOTS OF SIMULATION OUTPUTS

5.1. Pulse steer

5.1.1. B-double

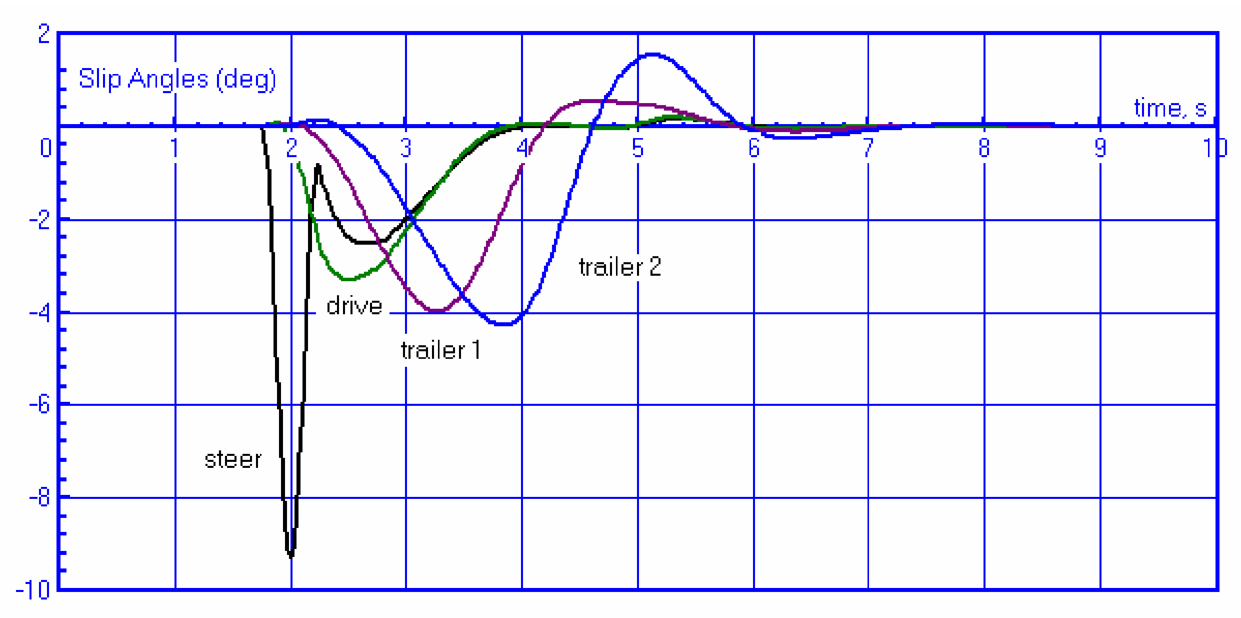

Figure 5.1. Tyre slip angles from B-double pulse steer simulation
Correponds to Fig. D1.1(a), page 71 in [1]

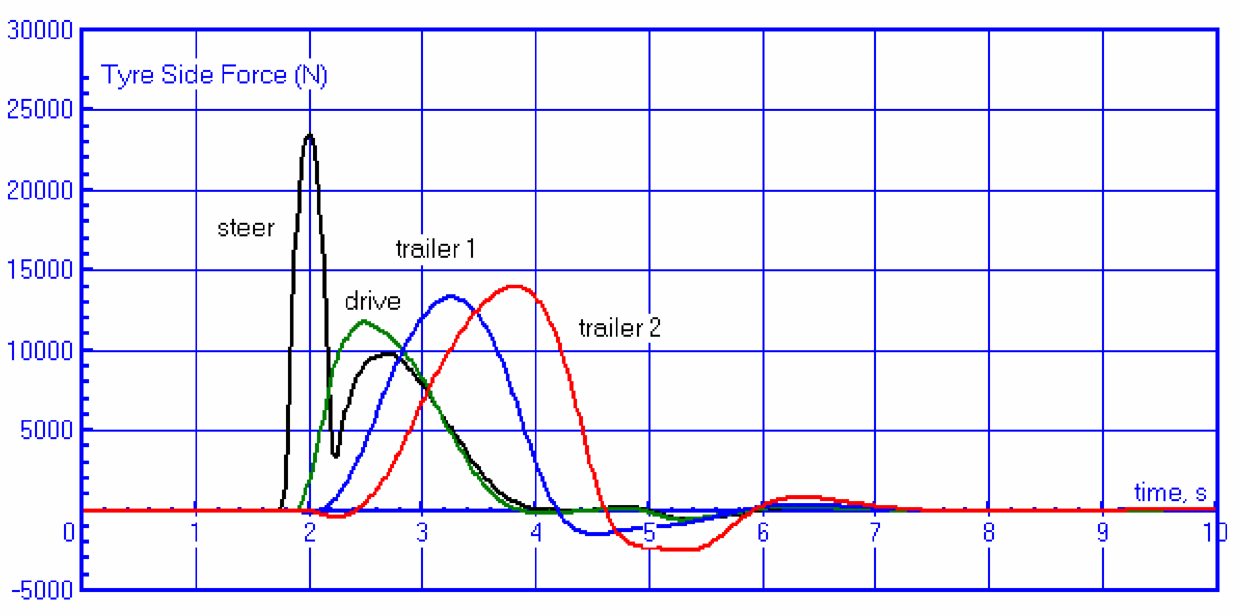

Figure 5.2. Tyre side forces from B-double pulse steer simulation
Correponds to Fig. D1.1(b), page 71 in [1]

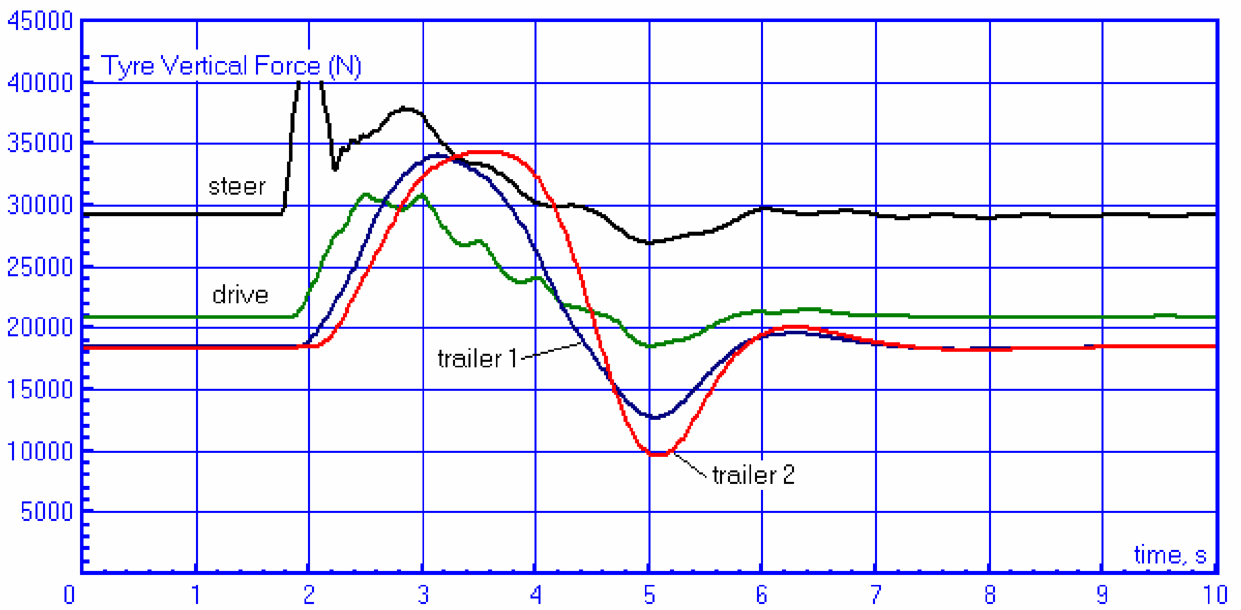

Figure 5.3. Tyre vertical forces from B-double pulse steer simulation
Correponds to Fig. D1.1(c), page 72 in [1]

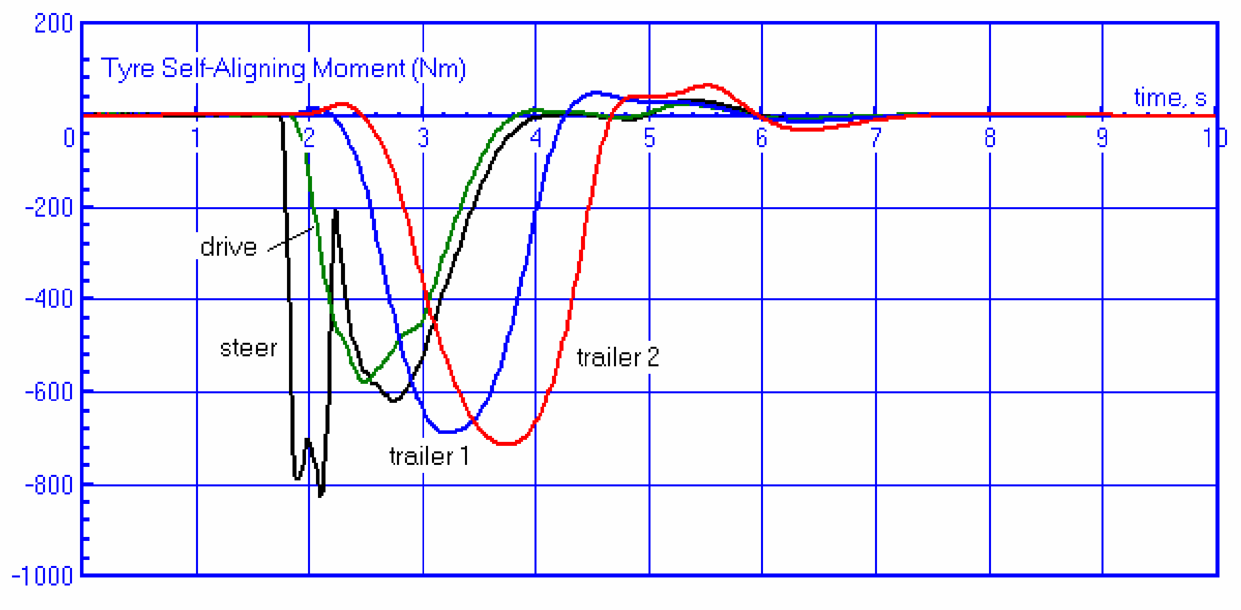

Figure 5.4. Tyre self-aligning moments from B-double pulse steer simulation
Correponds to Fig. D1.1(e), page 72 in [1]

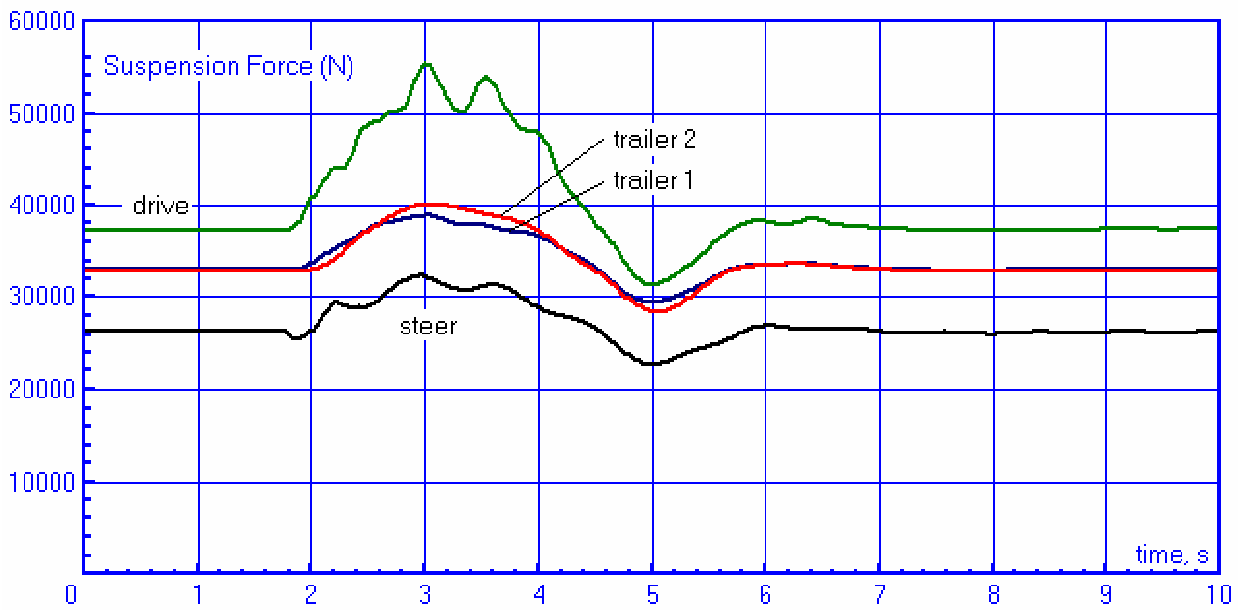

Figure 5.5. Suspension forces from B-double pulse steer simulation
Correponds to Fig. D1.1(f), page 73 in [1]

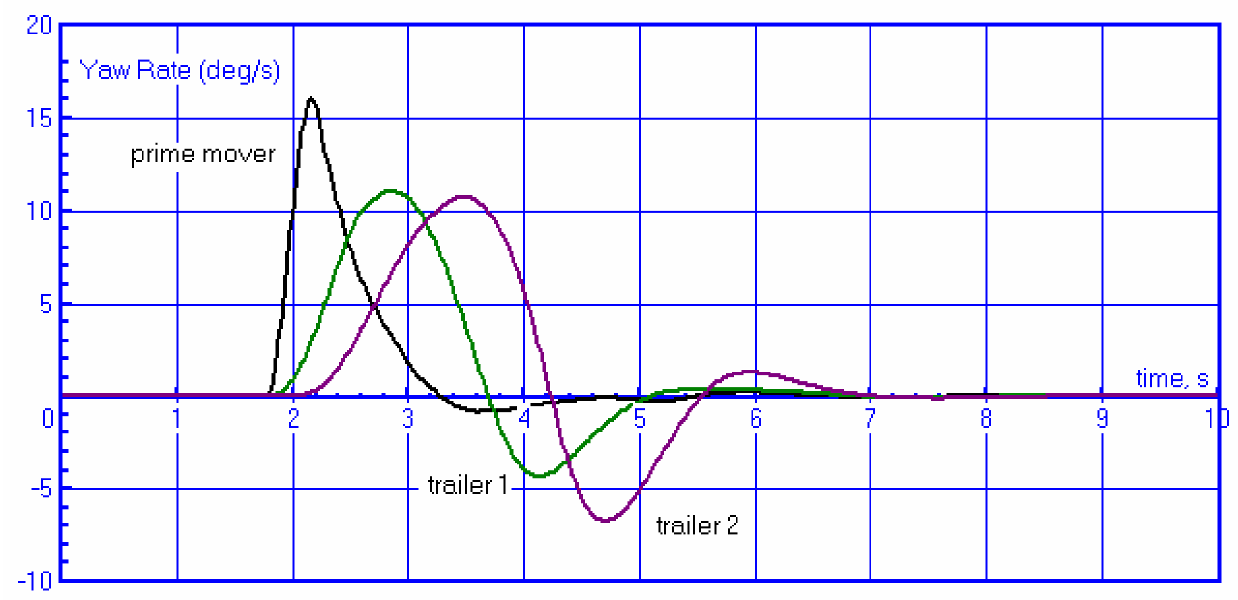

Figure 5.6. Yaw rates from B-double pulse steer simulation
Correponds to Fig. D1.1(g), page 73 in [1]

Figure 5.7. Yaw angles from B-double pulse steer simulation
Correponds to Fig. D1.1(h), page 74 in [1]

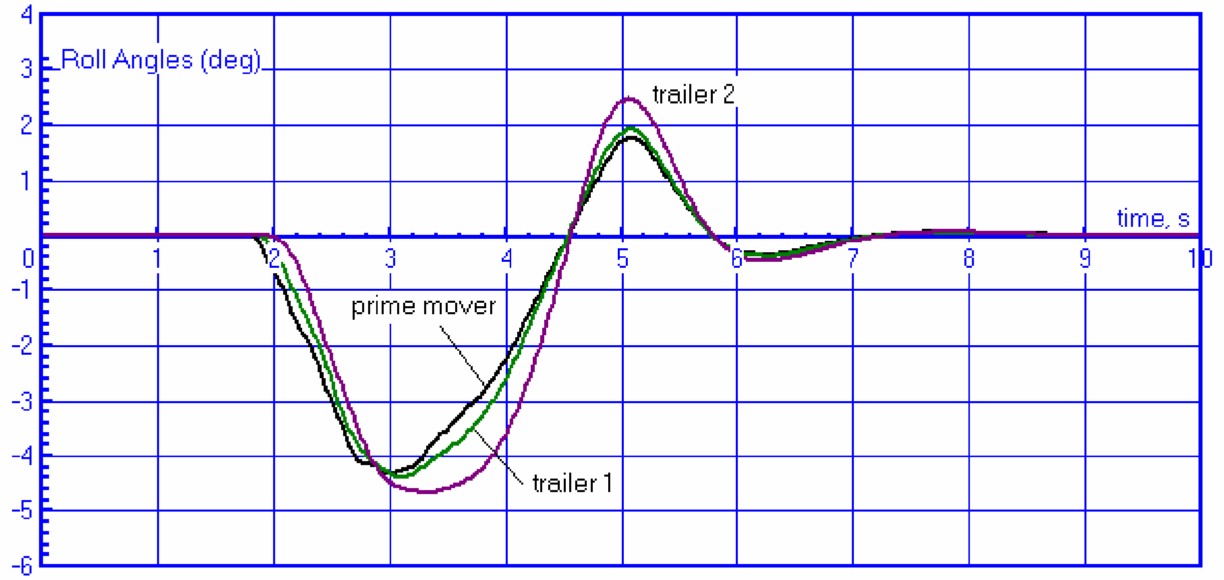

Figure 5.8. Roll angles from B-double pulse steer simulation
Correponds to Fig. D1.1(i), page 74 in [1]

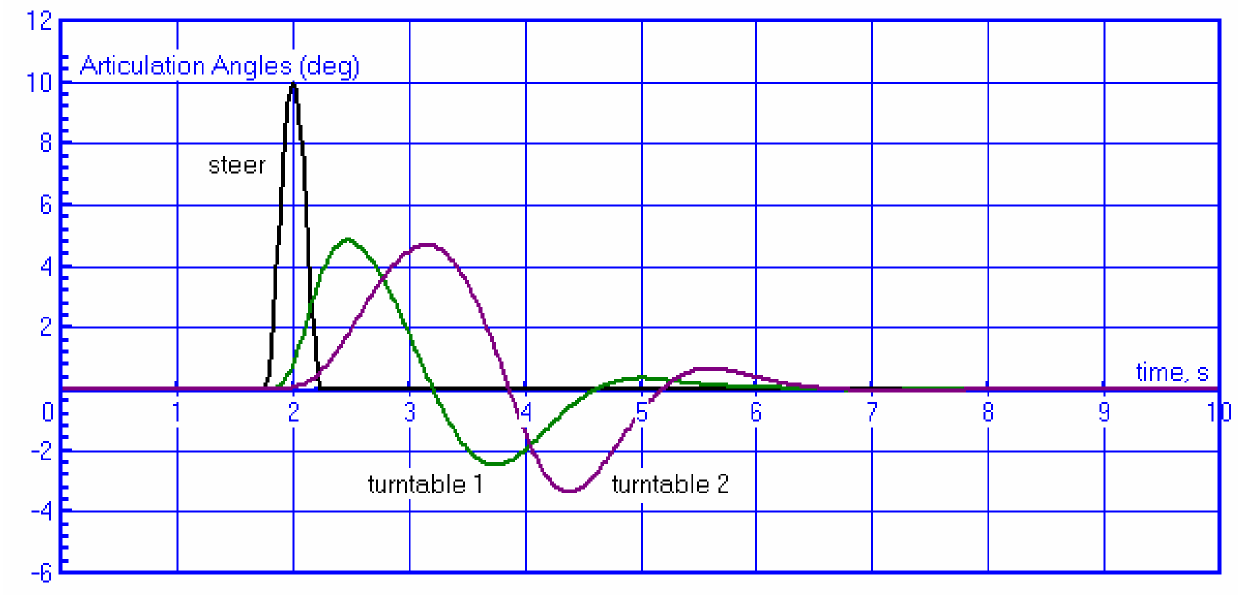

Figure 5.9. Articulation angles from B-double pulse steer simulation
Correponds to Fig. D1.1(j), page 75 in [1]

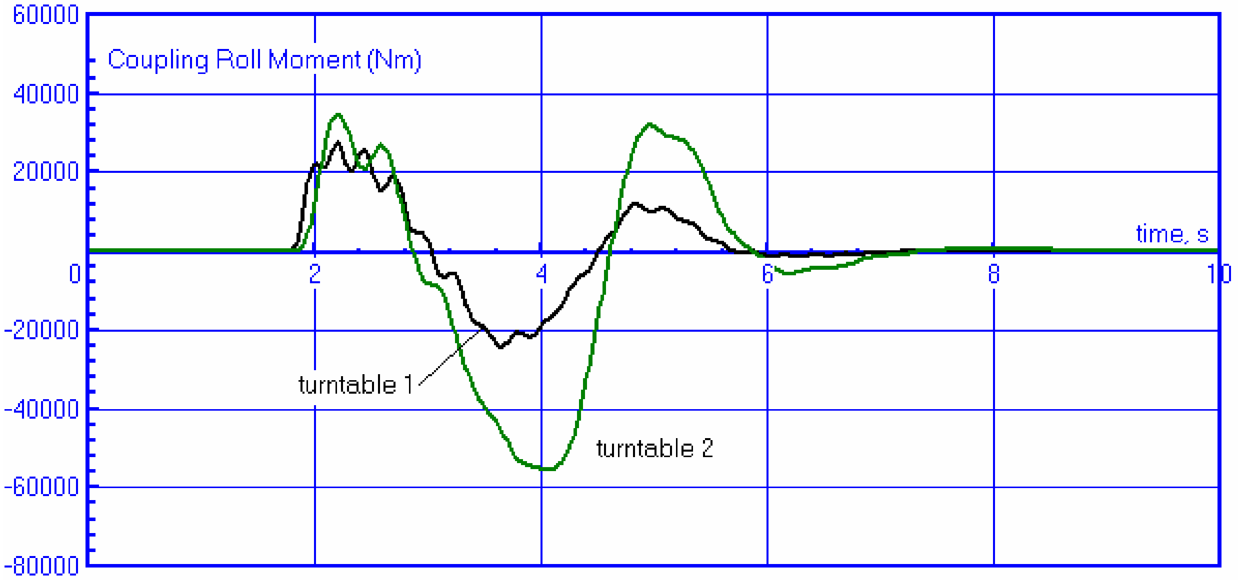

Figure 5.10. Coupling roll moments from B-double pulse steer simulation
Correponds to Fig. D1.1(k), page 75 in [1]

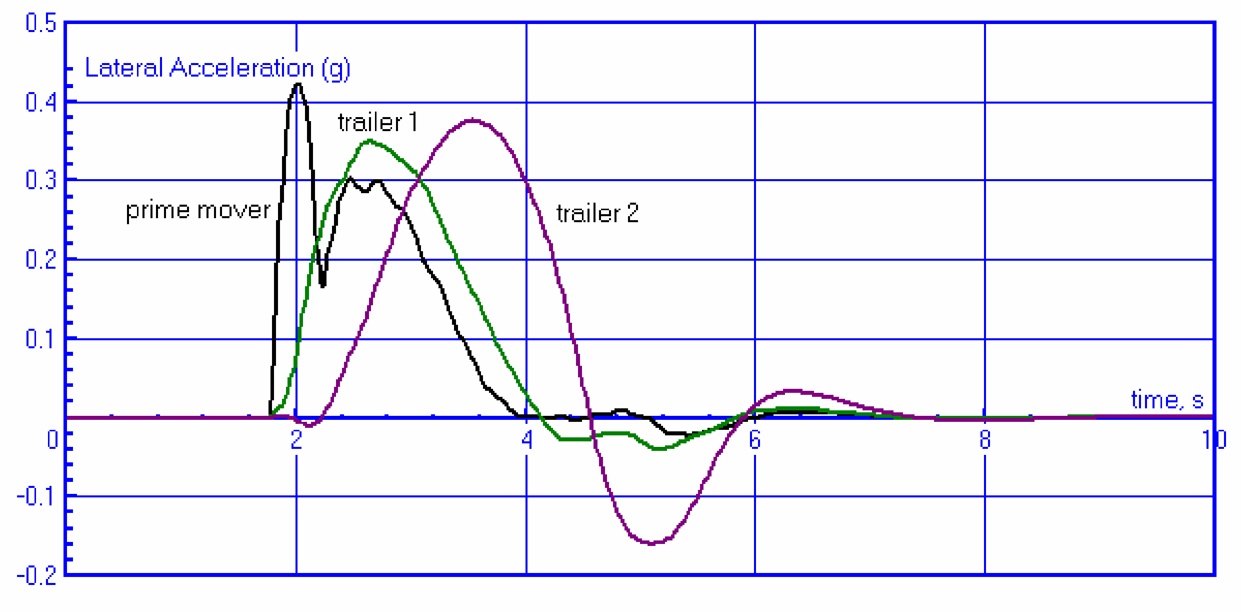

Figure 5.11. Lateral accelerations from B-double pulse steer simulation
Correponds to Fig. D1.1(l), page 76 in [1]

5.1.2. Truck/trailer

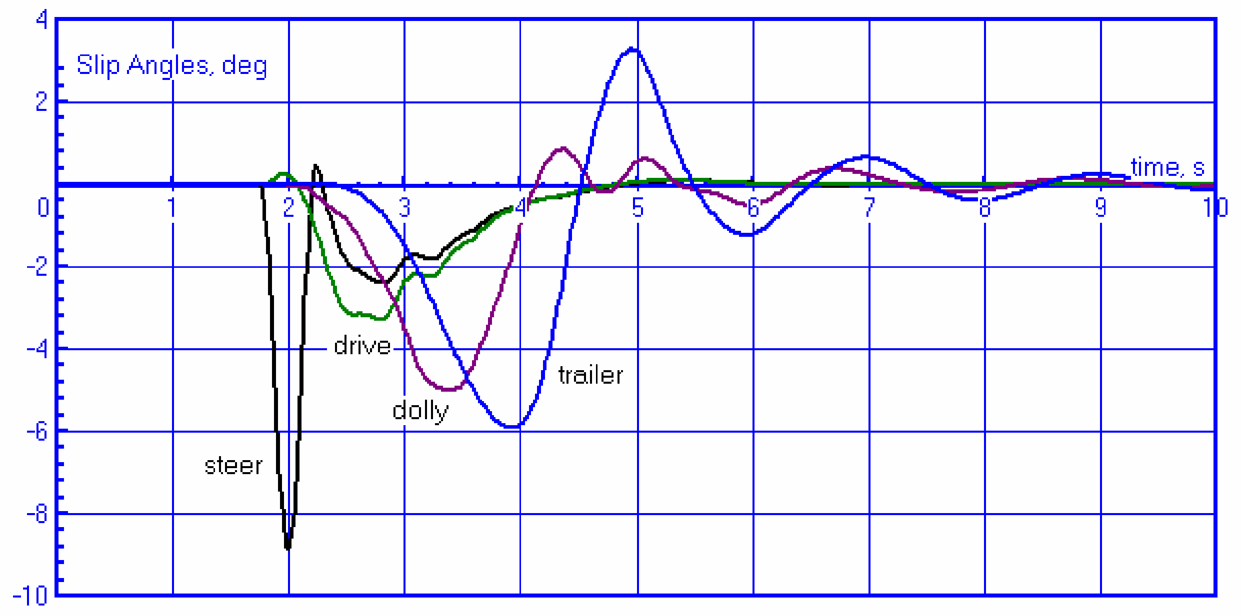

Figure 5.12. Tyre slip angles from the truck/trailer pulse steer simulation
Correponds to Fig. D1.2(a), page 76 in [1]

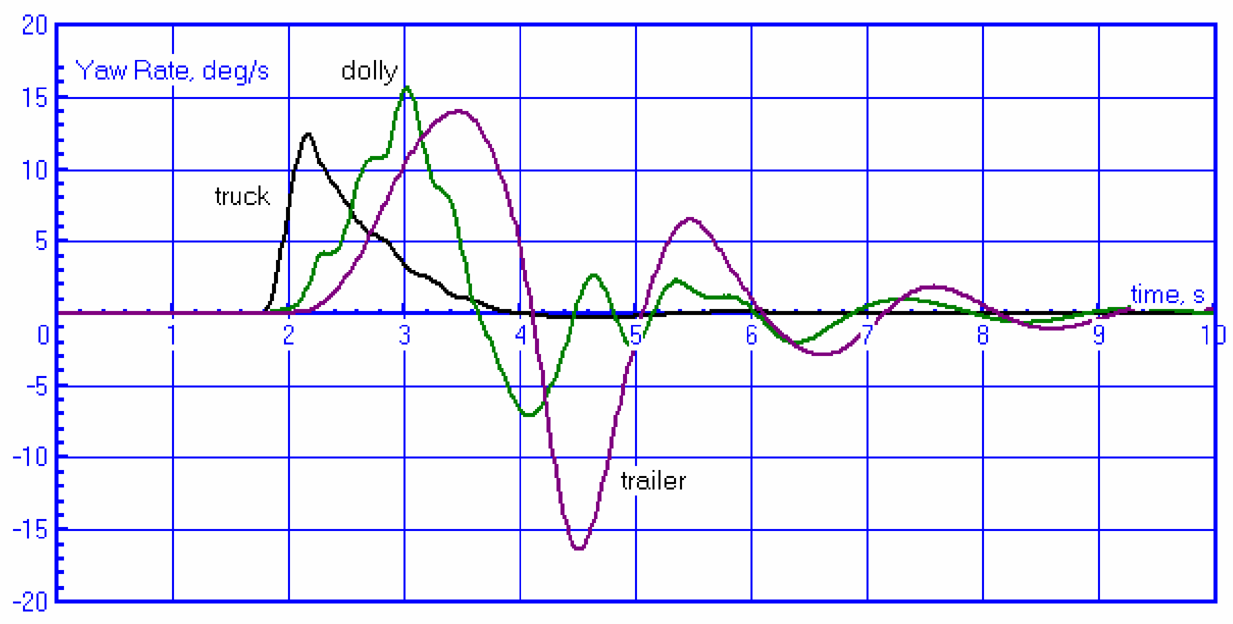

Figure 5.13. Yaw rates from the truck/trailer pulse steer simulation
Correponds to Fig. D1.2(b), page 77 in [1]

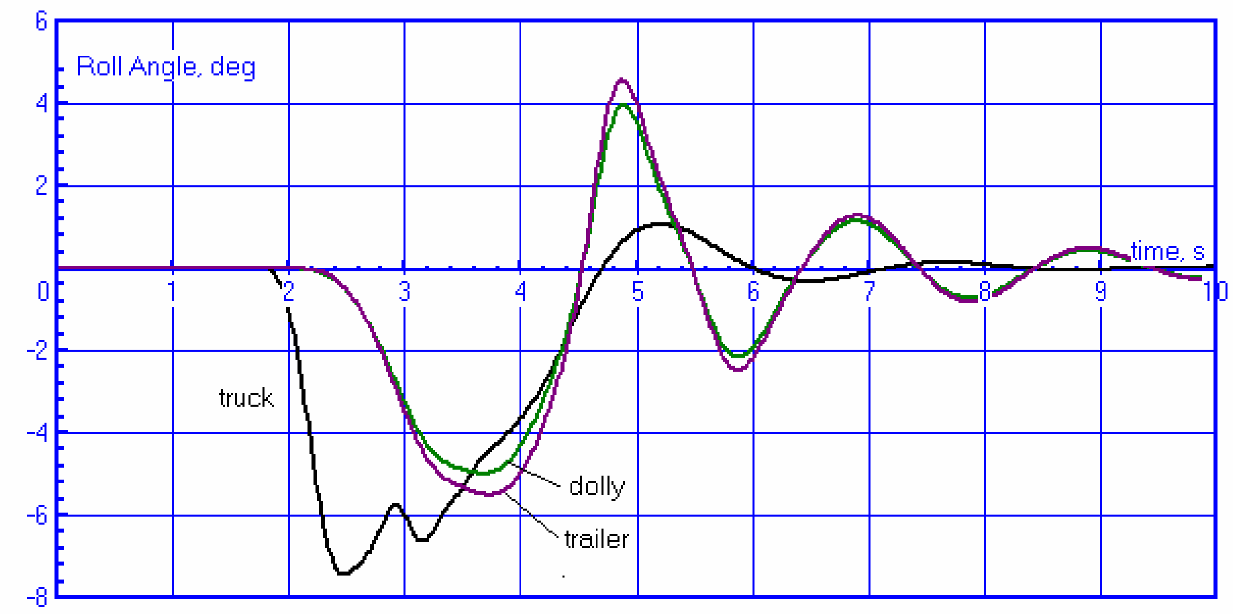

Figure 5.14. Roll angles from the truck/trailer pulse steer simulation
Correponds to Fig. D1.2(c), page 77 in [1]

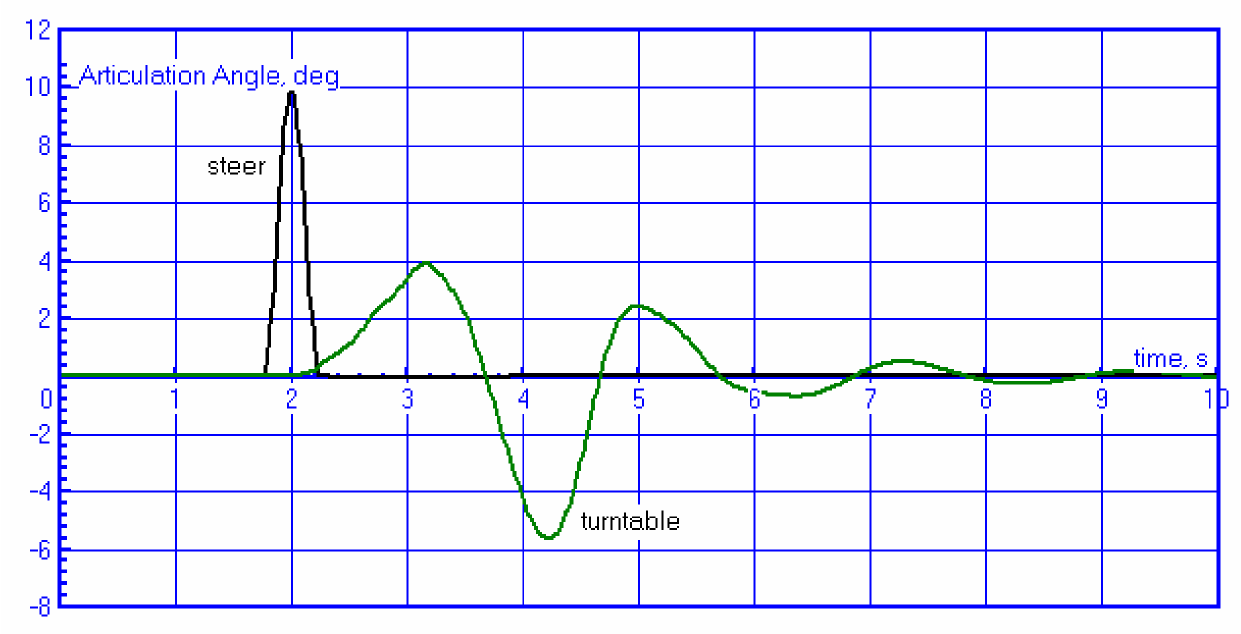

Figure 5.15. Articulation angles from the truck/trailer pulse steer simulation
Correponds to Fig. D1.2(d), page 78 in [1]

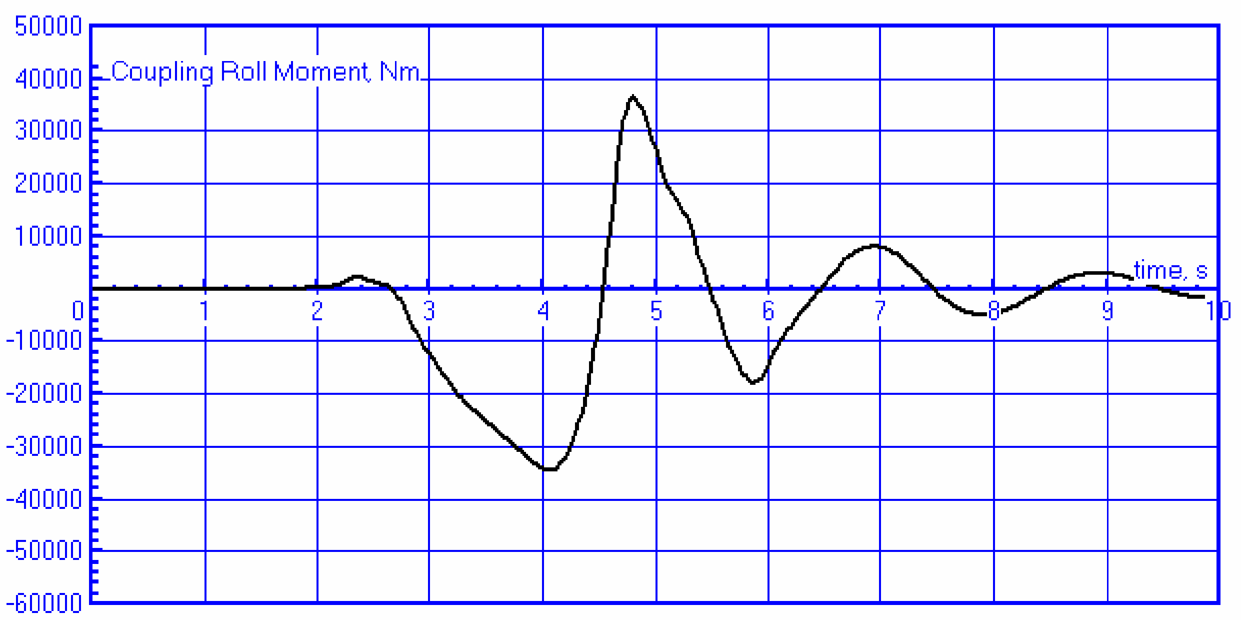

Figure 5.16. Turntable coupling roll moments from the truck/trailer pulse steer simulation
Correponds to Fig. D1.2(e), page 78 in [1]

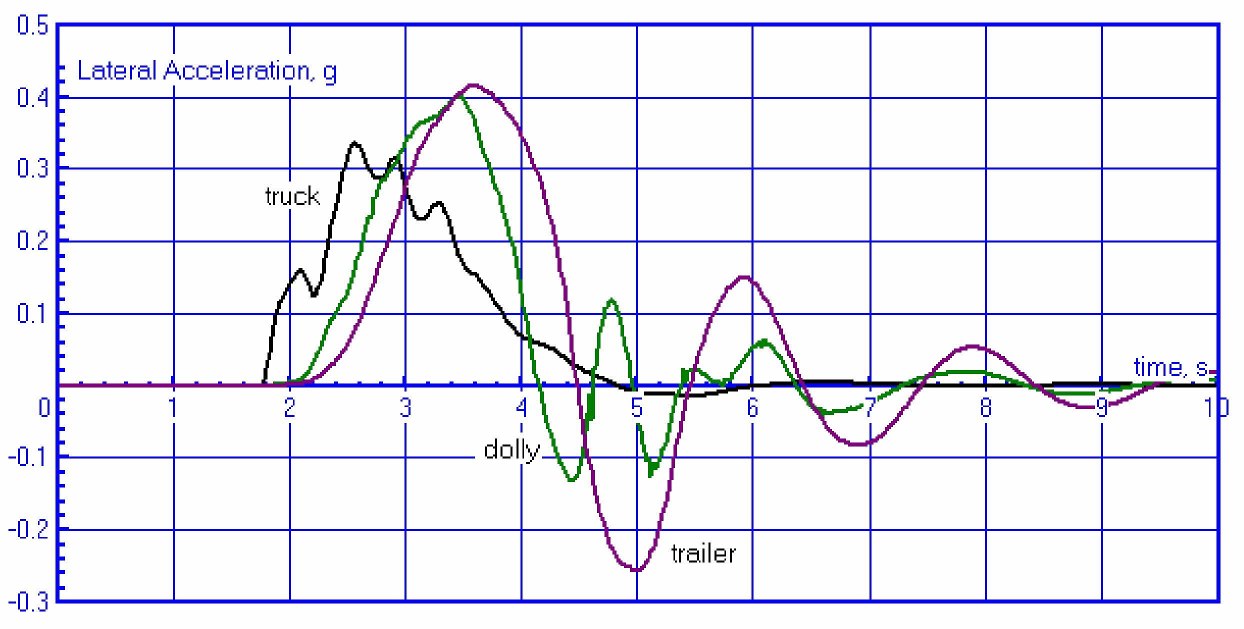

Figure 5.17. Lateral accelerations from the truck/trailer pulse steer simulation
Correponds to Fig. D1.2(g), page 79 in [1]

5.2. Step steer

5.2.1. B-double

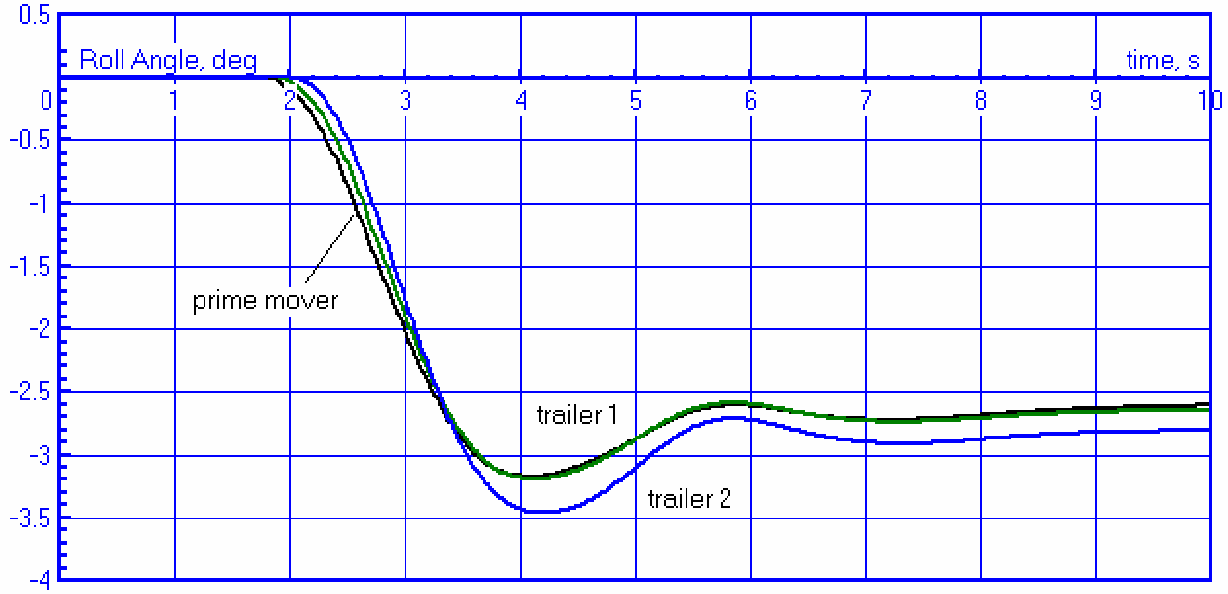

Figure 5.18. Roll angles from the B-Double step steer simulation
Correponds to Fig. D2.1(a), page 80 in [1]

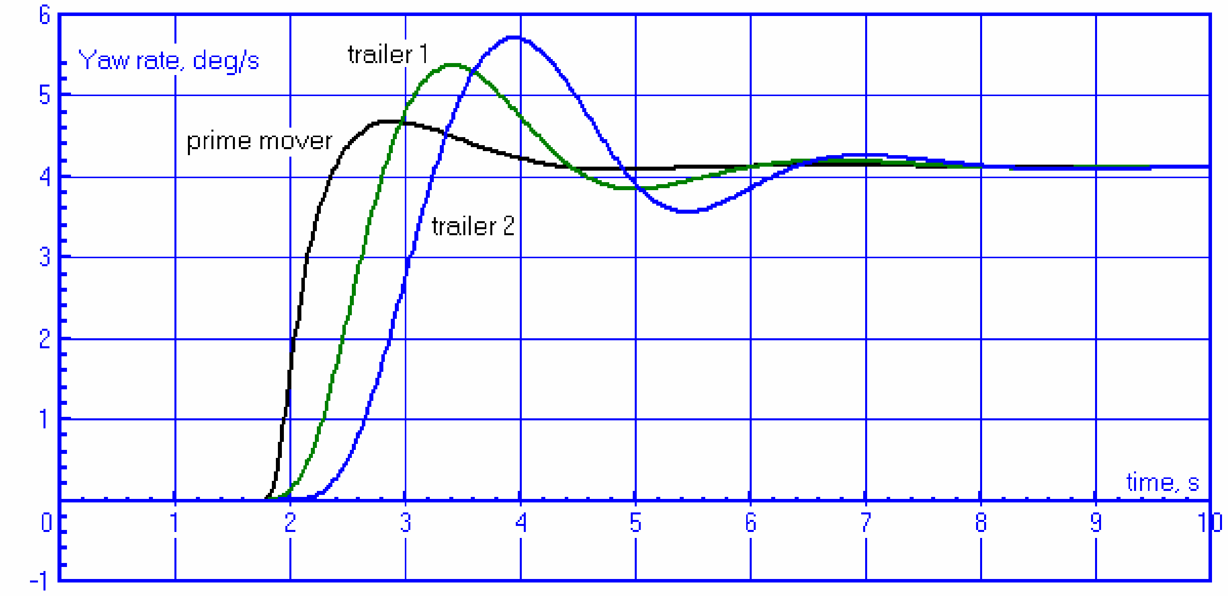

Figure 5.19. Yaw rates from the B-Double step steer simulation
Correponds to Fig. D2.1(b), page 80 in [1]

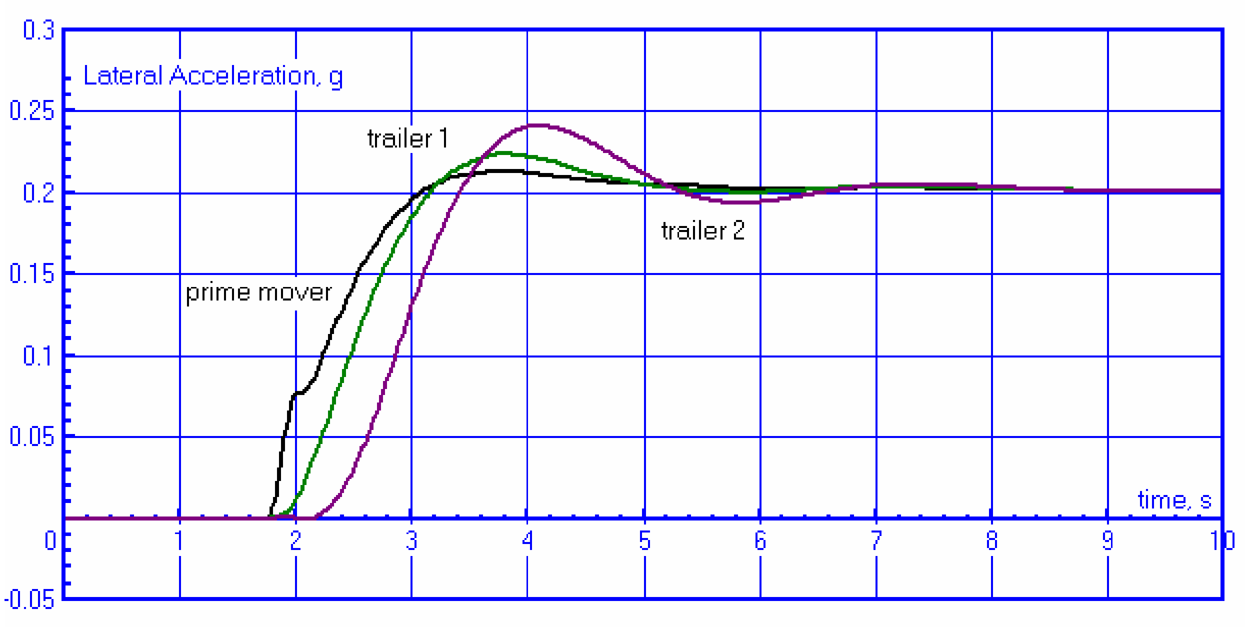

Figure 5.20. Lateral accelerations from the B-Double step steer simulation
Correponds to Fig. D2.1(c), page 81 in [1]

5.2.2. Truck/trailer

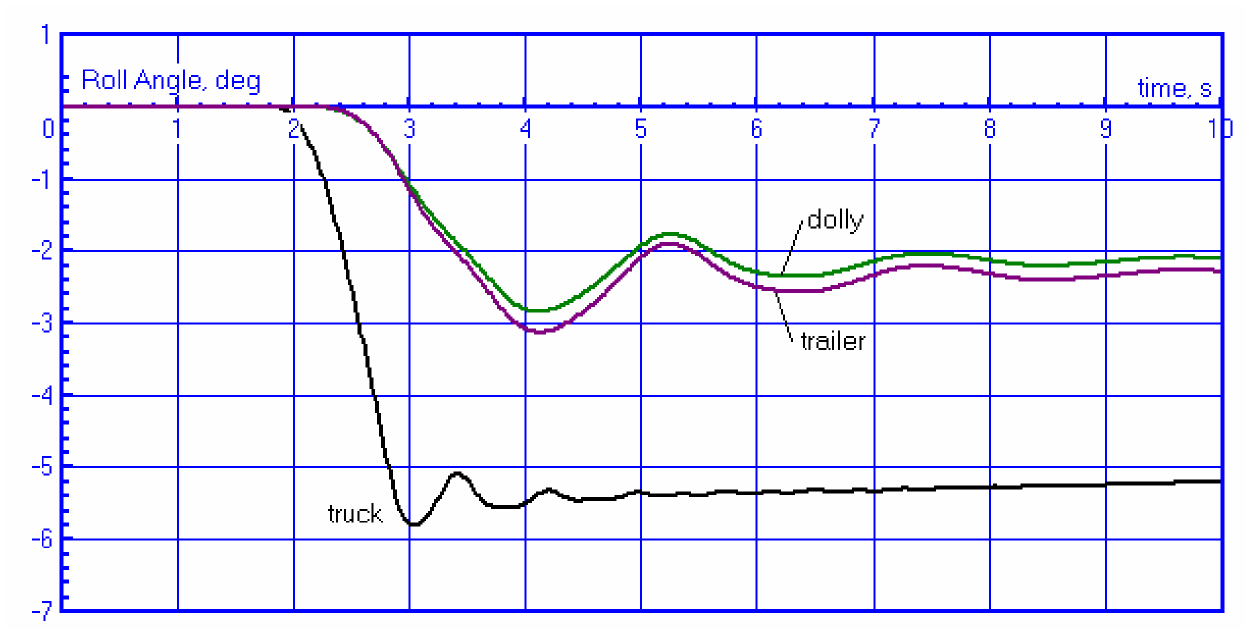

Figure 5.21. Roll angles from the truck/trailer step steer simulation
Correponds to Fig. D2.2(a), page 81 in [1]

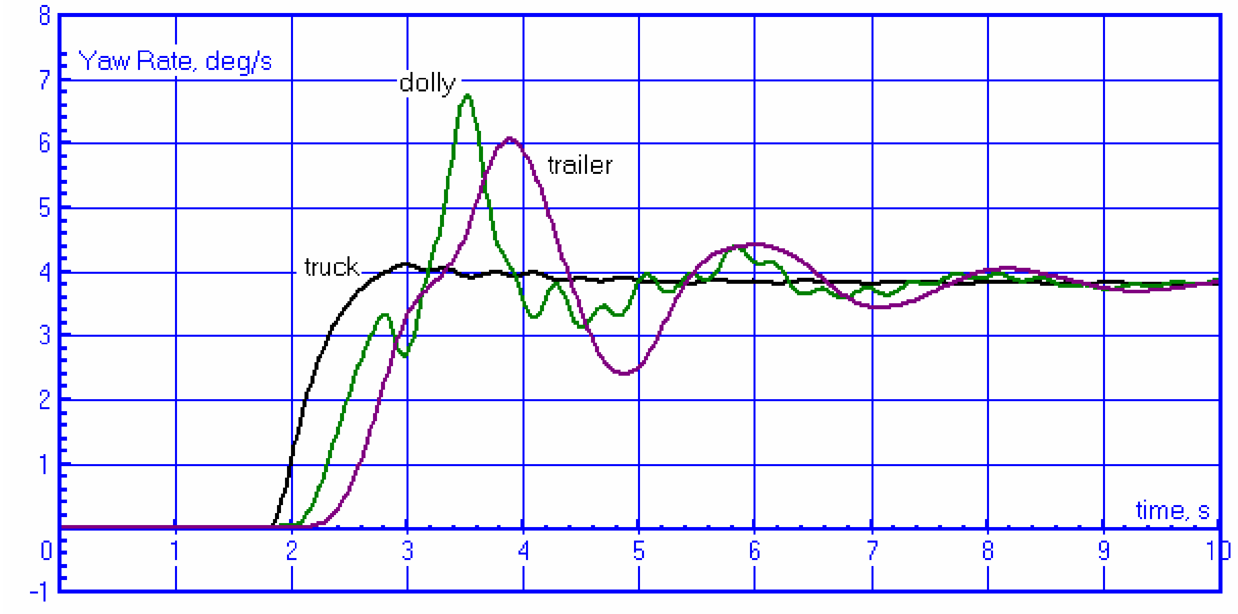

Figure 5.22. Yaw rates from the truck/trailer step steer simulation
Correponds to Fig. D2.2(b), page 82 in [1]

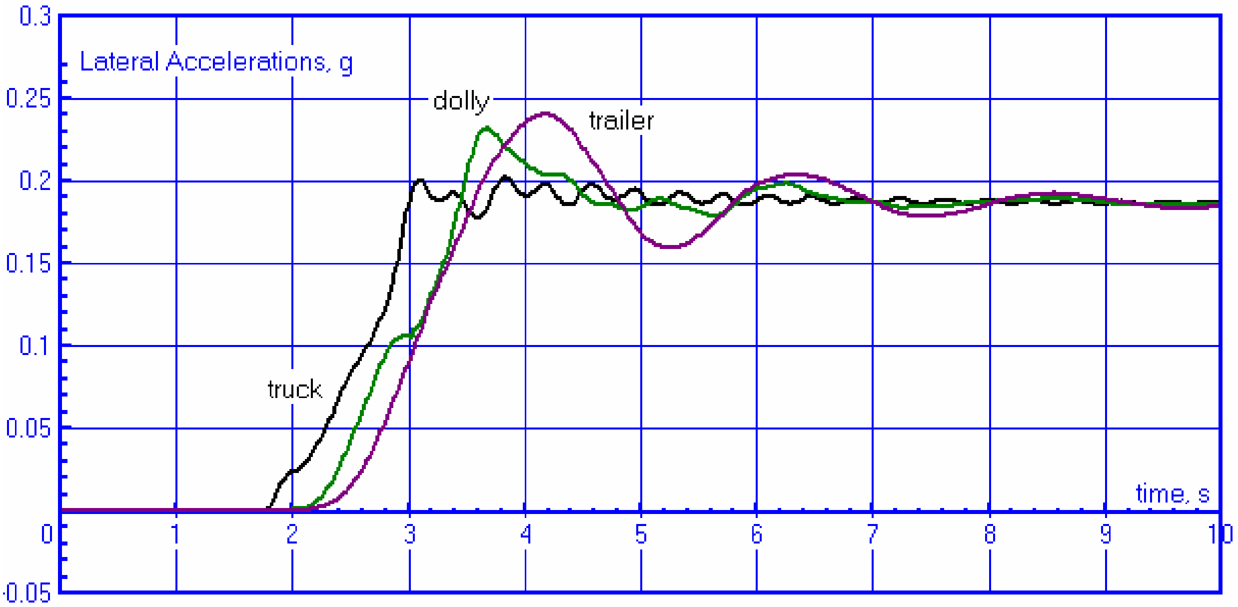

Figure 5.23. Lateral accelerations from the truck/trailer step steer simulation
Correponds to Fig. D2.2(c), page 82 in [1]

5.3. SAE lane change

5.3.1. B-double

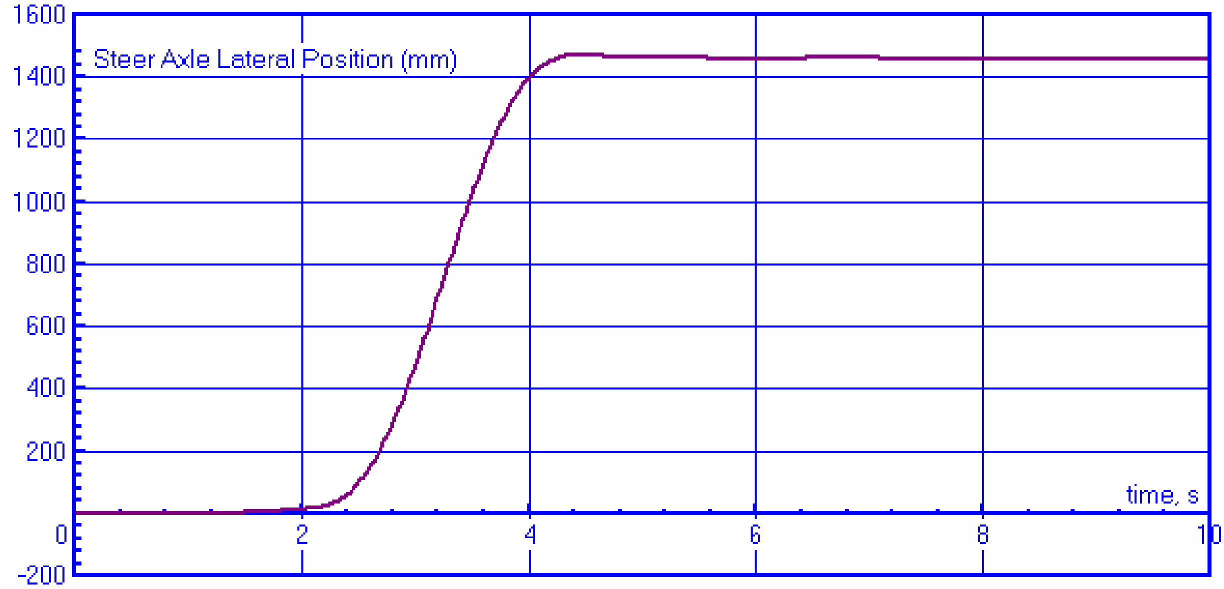

Figure 5.24. Path from the B-Double SAE lane change simulation
Correponds to Fig. D3.1(a), page 83 in [1]

Figure 5.25. Steer axle lateral position error from the B-Double SAE lane change simulation
Correponds to Fig. D3.1(b), page 83 in [1]

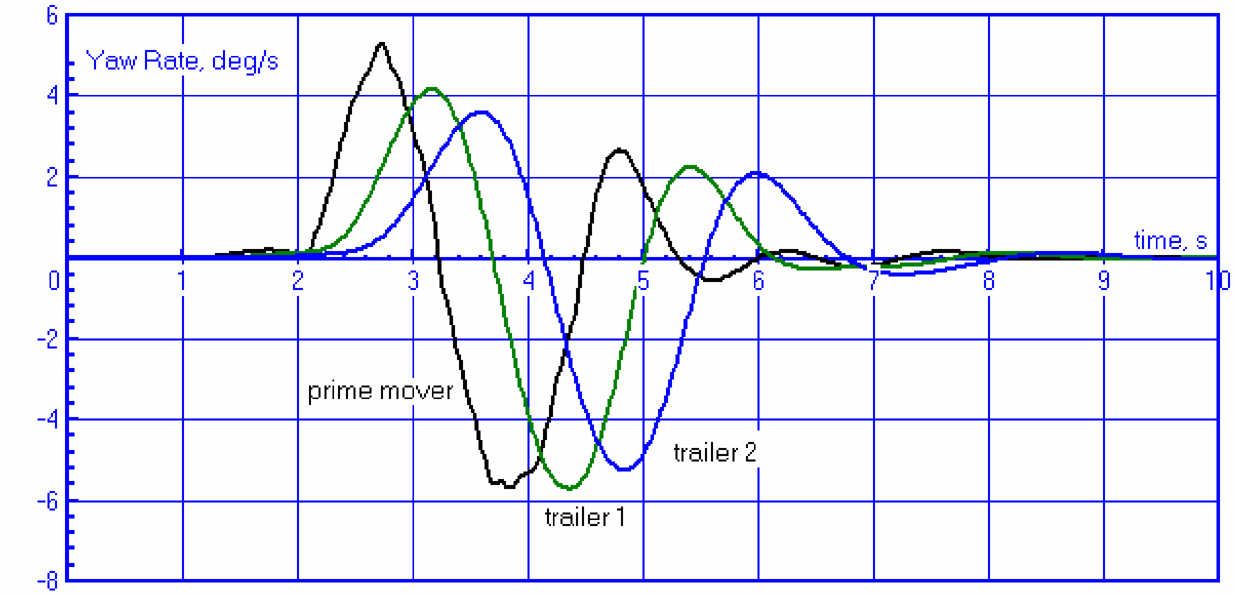

Figure 5.26. Yaw rates from the B-Double SAE lane change simulation
Correponds to Fig. D3.1(c), page 84 in [1]

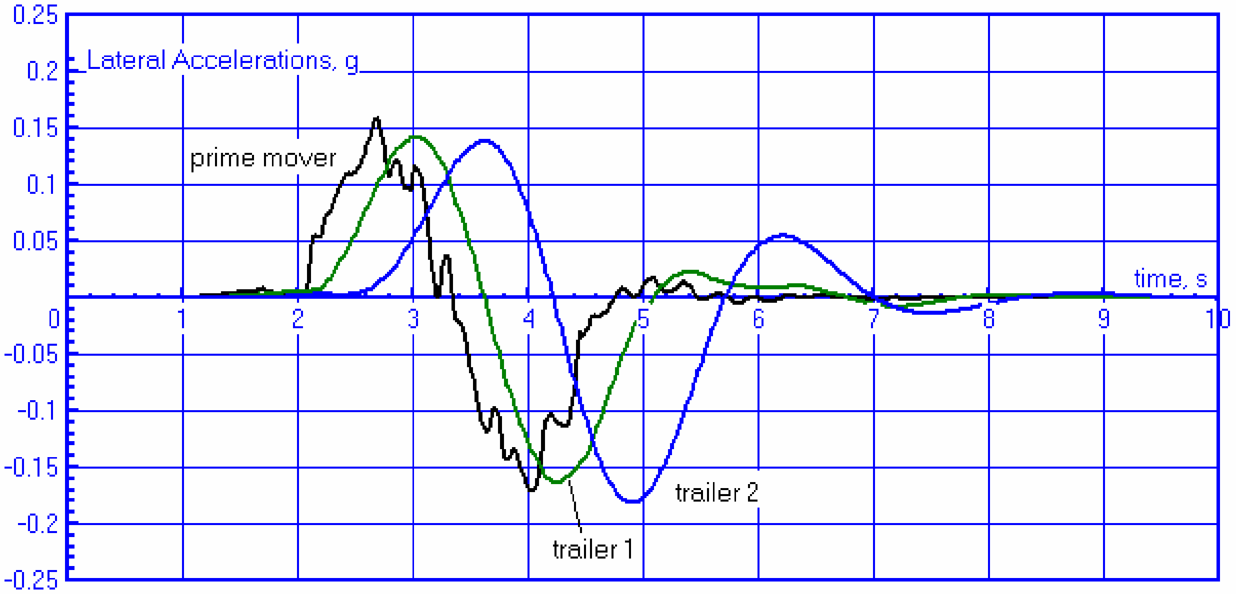

Figure 5.27. Lateral accelerations from the B-Double SAE lane change simulation
Correponds to Fig. D3.1(d), page 84 in [1]

5.3.2. Truck/trailer

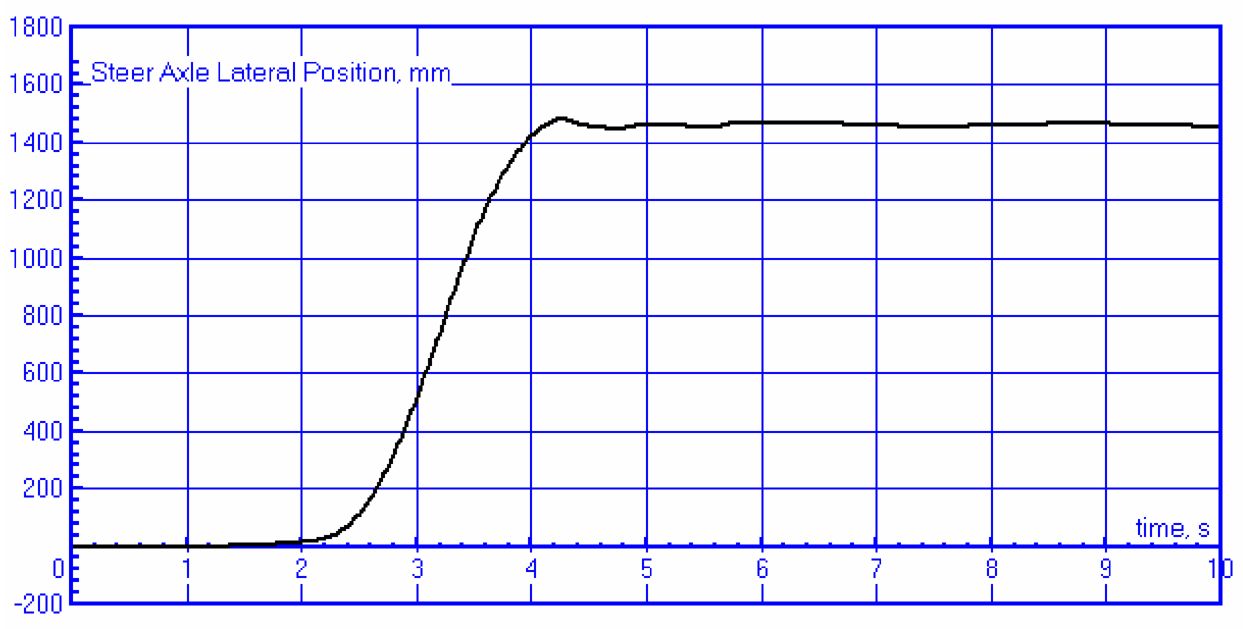

Figure 5.28. Path from the truck/trailer SAE lane change simulation
Correponds to Fig. D3.2(a), page 85 in [1]

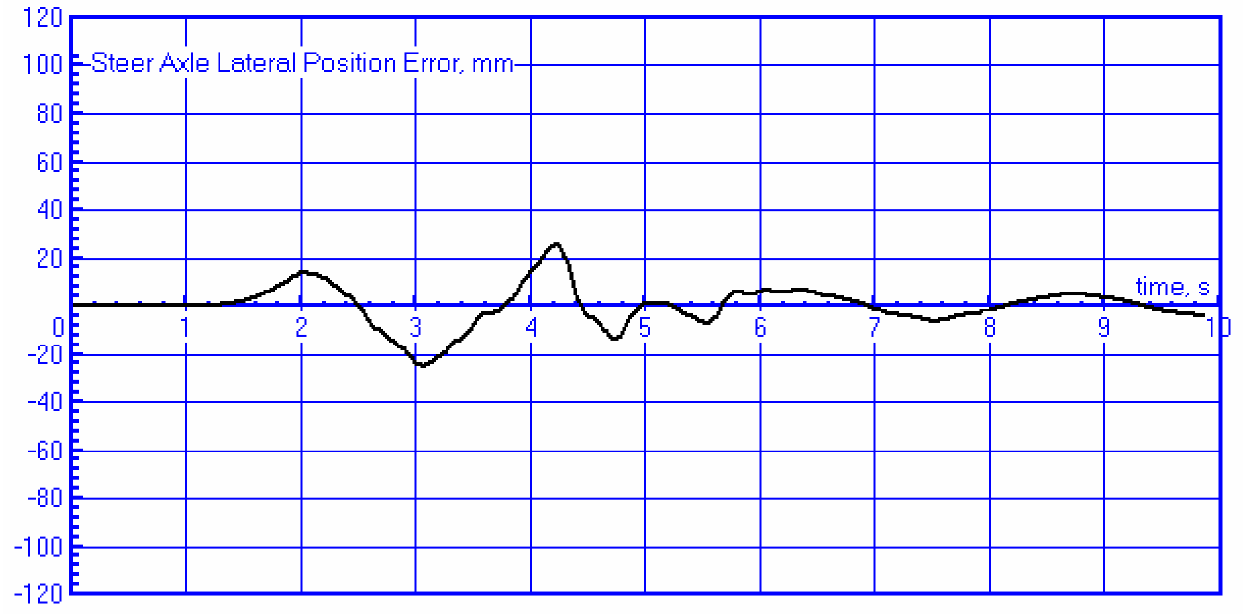

Figure 5.29. Lateral position error from the truck/trailer SAE lane change simulation
Correponds to Fig. D3.2(b), page 86 in [1]

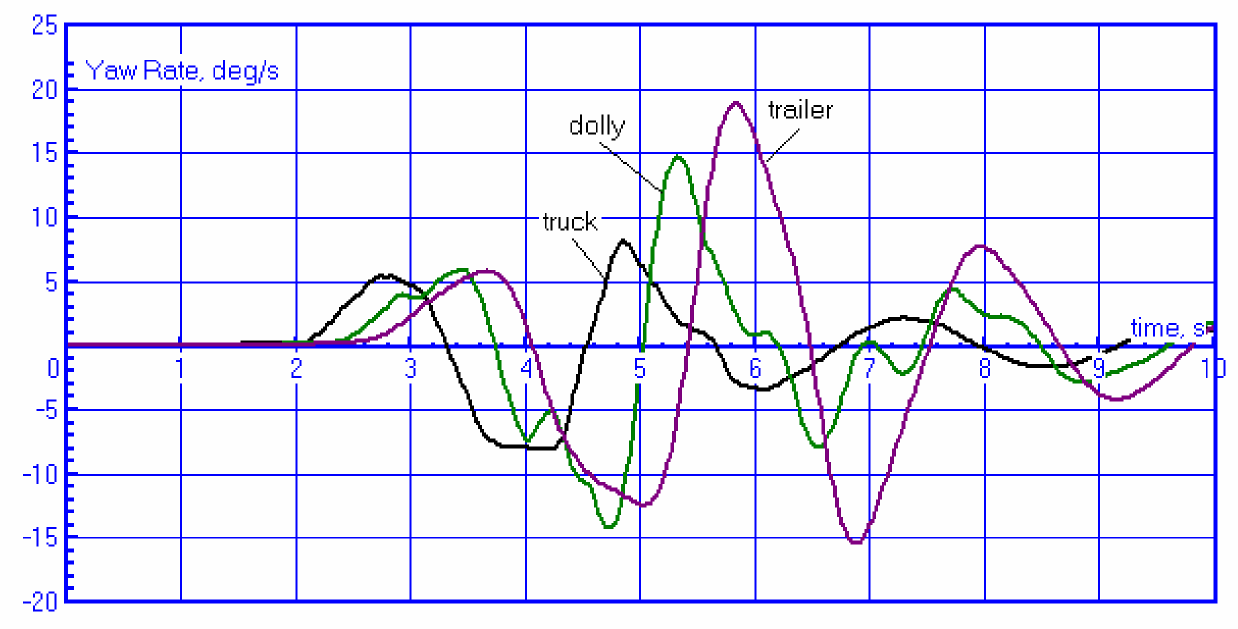

Figure 5.30. Yaw rates from the truck/trailer SAE lane change simulation
Correponds to Fig. D3.2(c), page 86 in [1]

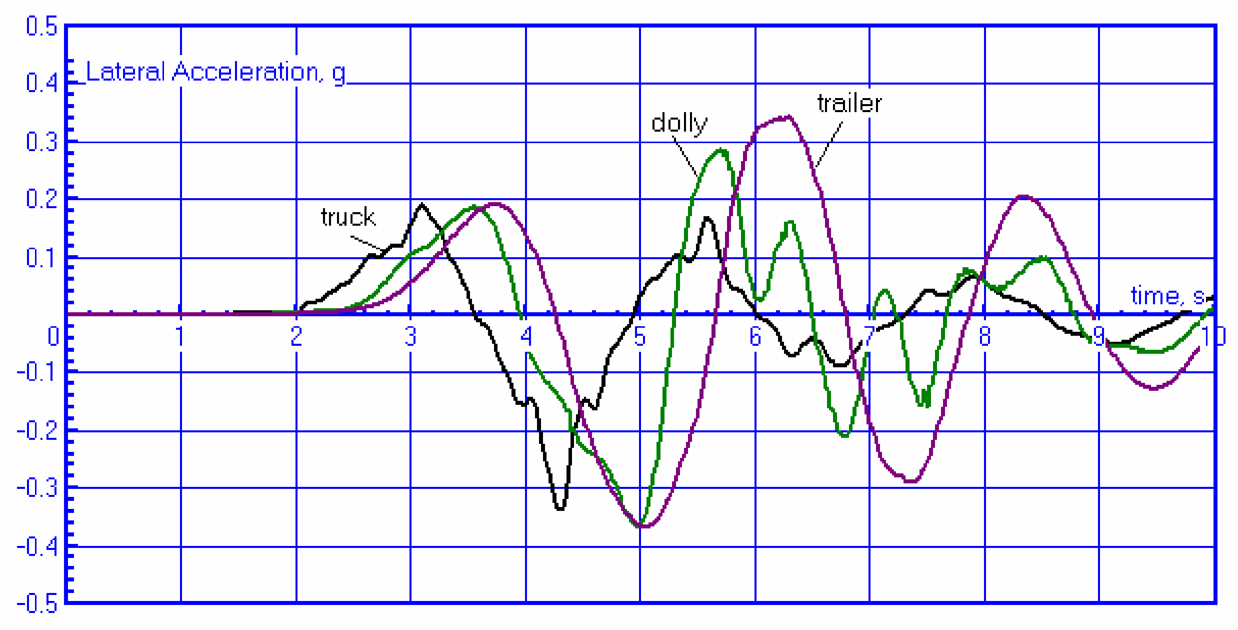

Figure 5.31. Lateral accelerations from the truck/trailer SAE lane change simulation
Correponds to Fig. D3.2(d), page 87 in [1]

5.4. Low-speed 90º turn

5.4.1. B-double

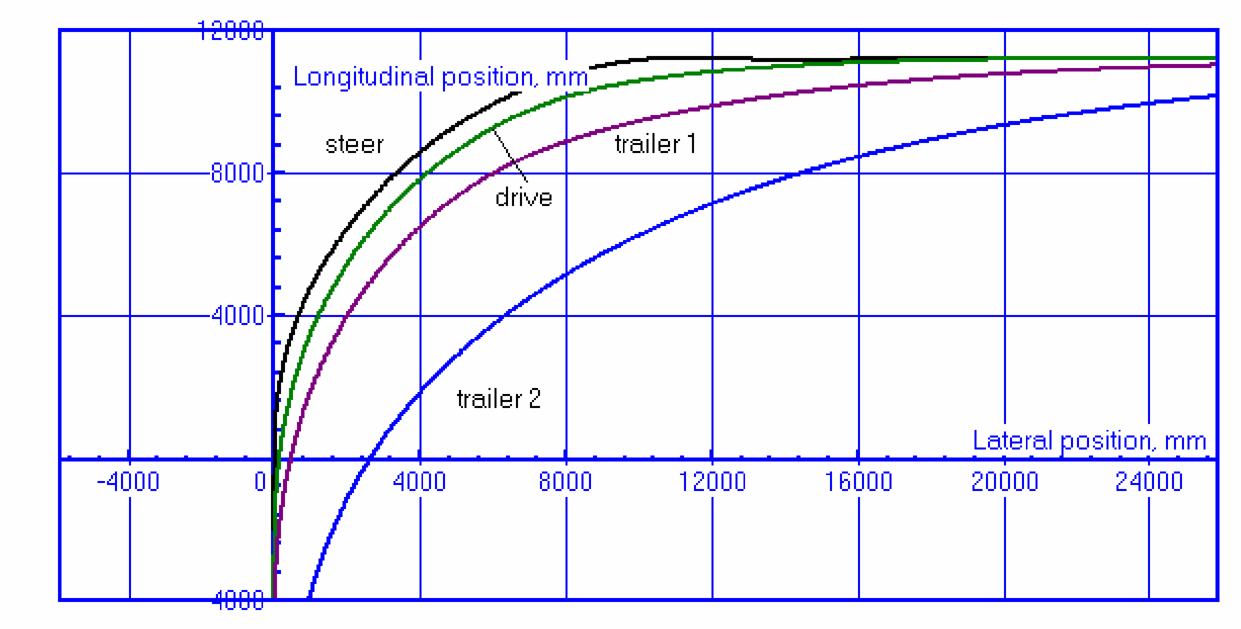

Figure 5.32. Trajectories from the B-double low-speed 90º turn simulation
Correponds to Fig. D4.1(a), page 88 in [1]

5.4.2. Truck-trailer

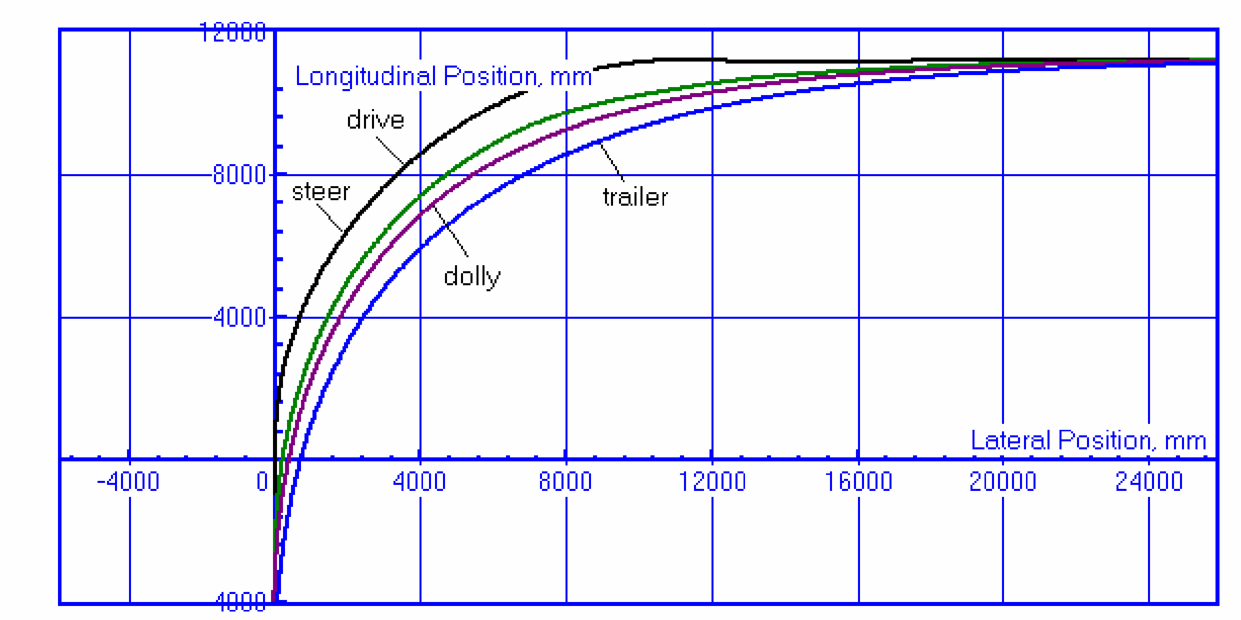

Figure 5.33. Trajectories from the truck/trailer low-speed 90º turn simulation
Correponds to Fig. D4.2(a), page 89 in [1]

REFERENCES

1. Comparison of Modelling Systems for Performance-Based Assessments of Heavy Vehicles. National Road Transport Commission, Melbourne, Australia. http://www.ntc.gov.au/filemedia/Reports/ComparisonModellingSystemsPerfor.doc