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AUTOMOTIVE CONFERENCE 2022
North America

Design of vehicle platooning controller with V2V communication

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Design of vehicle platooning controller with V2V communication

Platooning Controller example

Design Controller for Vehicle Platooning

Tune spacing controller for trailing vehicles in a platoon using PID Tuner.

Open Live Script

Simulink Control Design™
Model-Based PID Controller Tuning

R2021b

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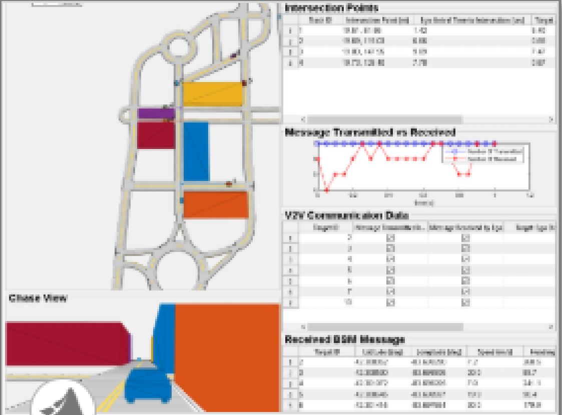
V2V example



Intersection Movement Assist Using Vehicle-to-Vehicle Communication

Design intersection movement assist application using V2V communication.

Open Example

Automated Driving Toolbox™

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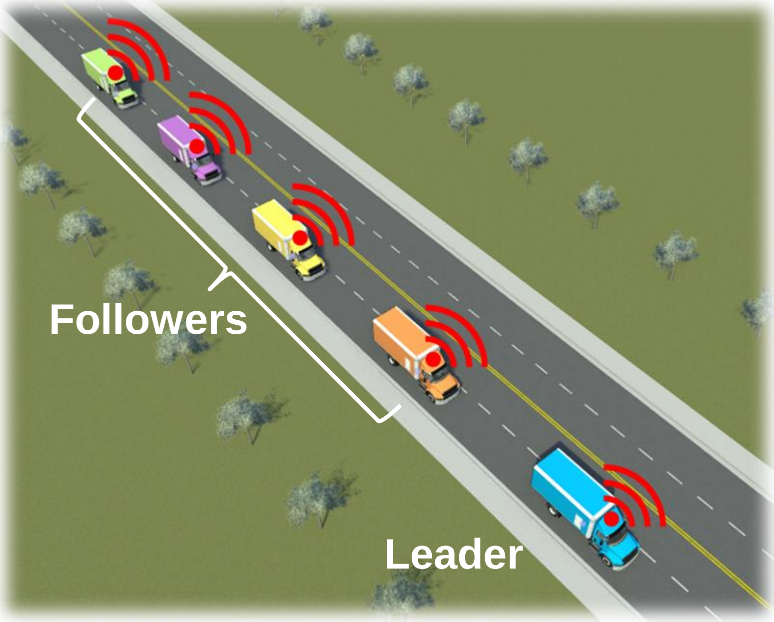
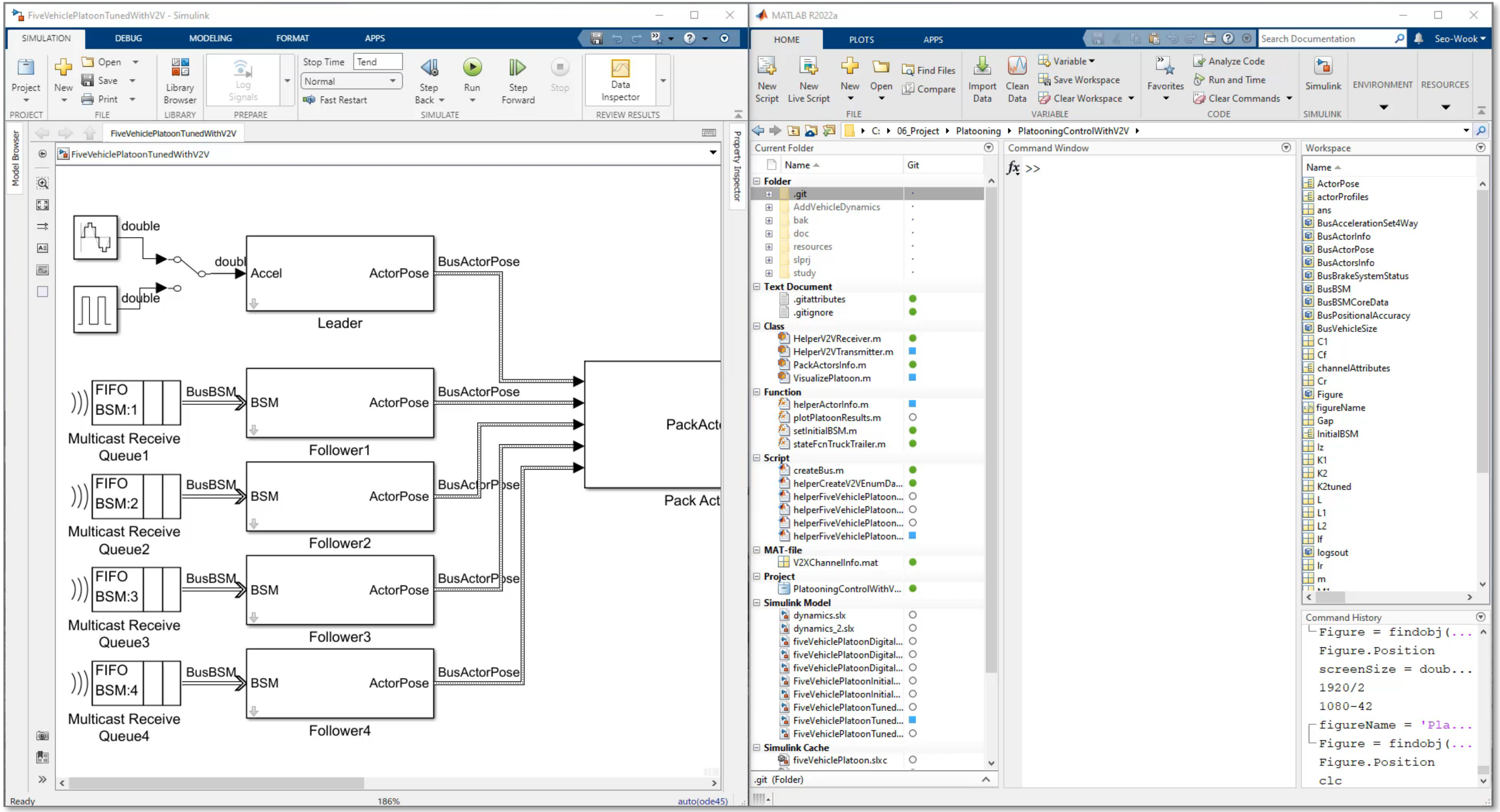
Platooning with V2V

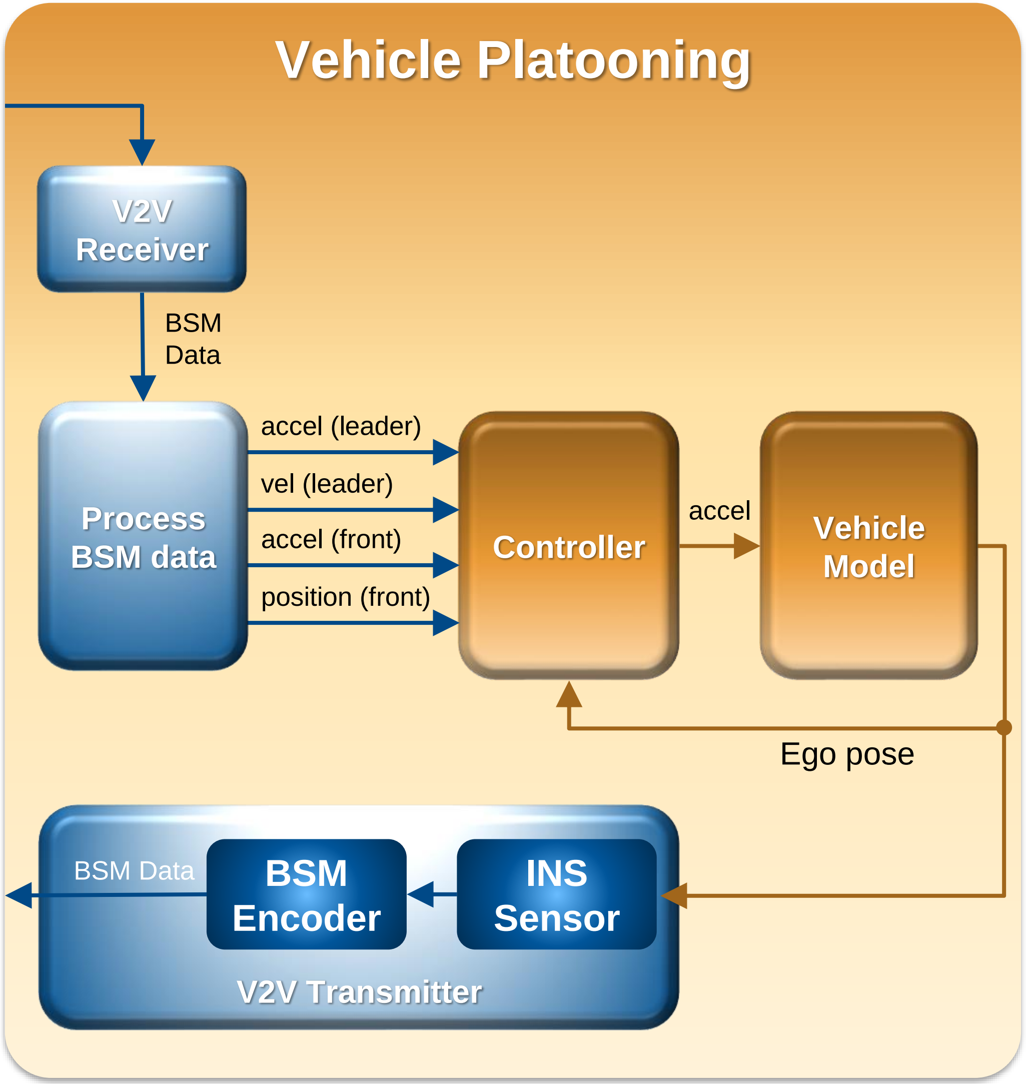


Simulation for vehicle platooning controller with V2V communication



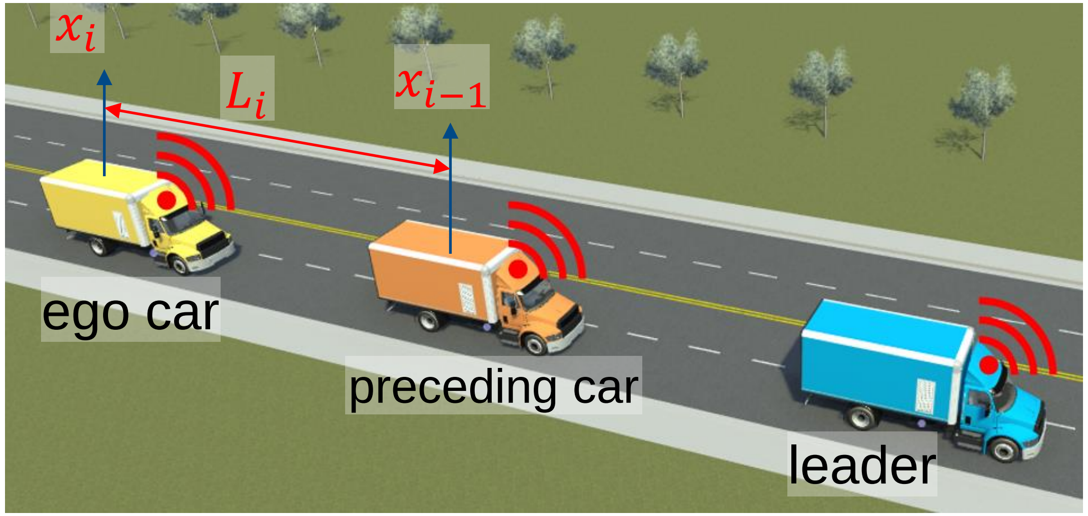
Platooning: components

- Information flow via V2V
  - Obtains the position and movement information of the other vehicles in the platoon via V2V
- Distributed controller
  - Sliding mode control: every controller share the same structure and parameters
  - Constant spacing: every car maintains a constant spacing from the preceding car
- Vehicle model
  - Truck-trailer kinematic model
  - A single track 3DOF rigid vehicle body (bicycle model)



Platooning: problem statement

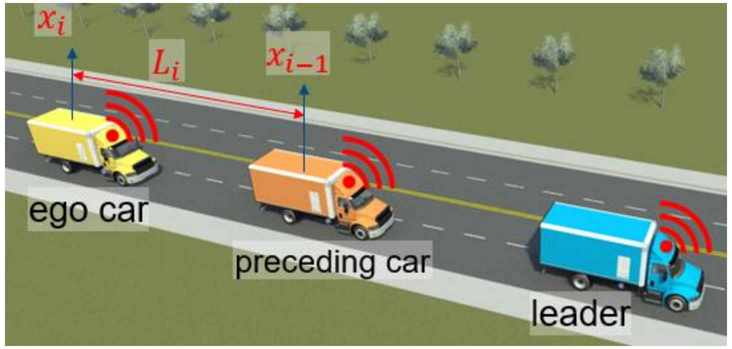
- Problem setup:
  - A given acceleration profile drives the lead vehicle
  - Every trailing vehicle is controlled by a controller based on the position and motion information of the other vehicles in the platoon
- Requirement:
  - Define spacing error: $\varepsilon_i = L_i - (x_{i-1} - x_i)$
  - Individual stability
    - $\varepsilon_i \rightarrow 0$: spacing error goes to zero if predecessor maintains constant speed.
  - String stability
    - spacing error does not amplify downstream.



where L_i is the desired spacing that includes the vehicle length.

Controller with sliding mode control

$$a_{ego} = C_1 a_{lead} + (1 - C_1) a_{front} - K_1(v_{ego} - v_{lead}) - K_2(x_{ego} - x_{front} + L)$$



Trade off between lead car and preceding car

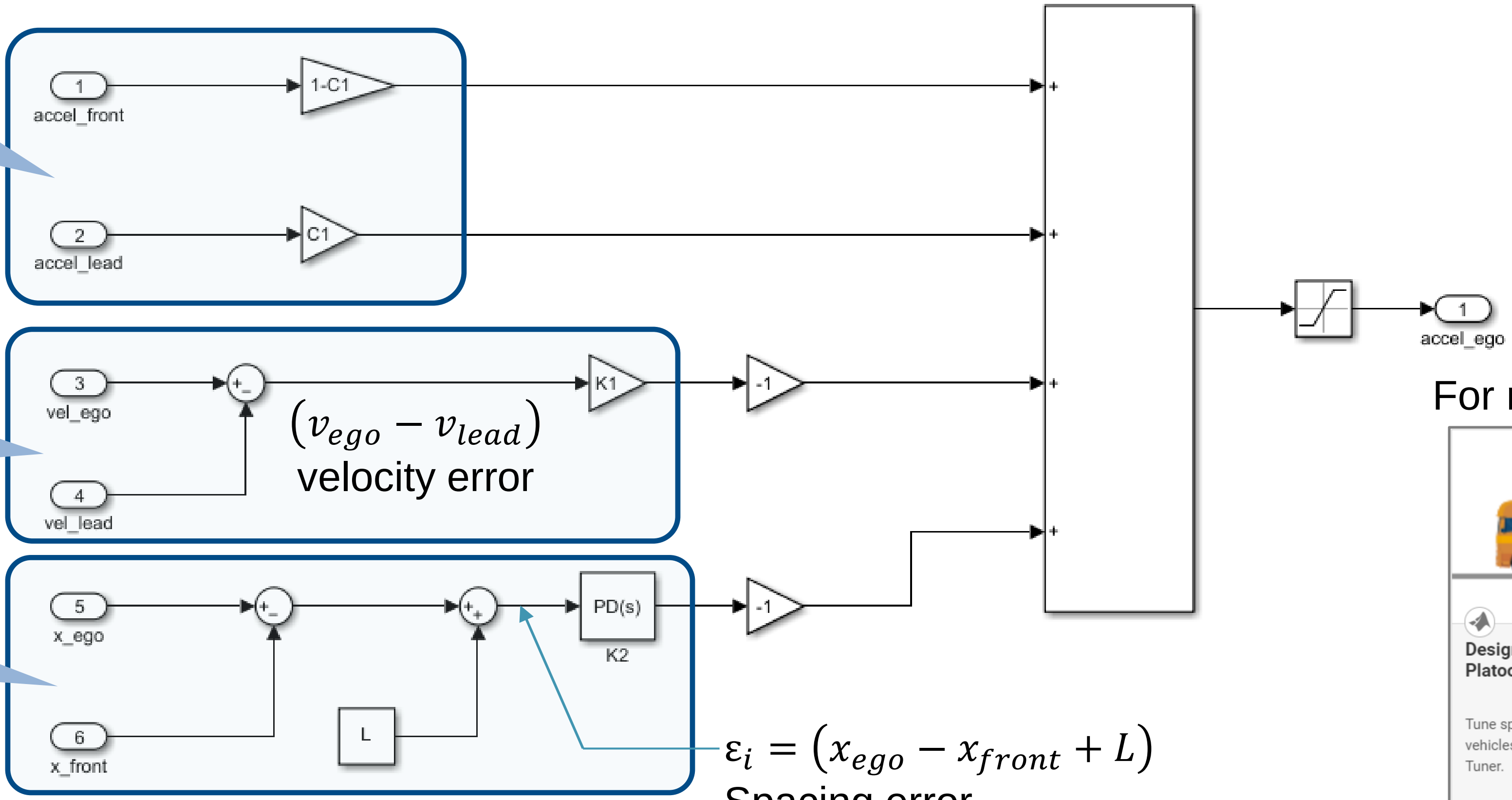
$C_1 a_{lead} + (1 - C_1) a_{front}$

Ego velocity will converge to lead velocity

$-K_1(v_{ego} - v_{lead})$

Spacing error will converge to zero

$-K_2(x_{ego} - x_{front} + L)$



$\varepsilon_i = (x_{ego} - x_{front} + L)$
Spacing error
= ego - preceding car position

For more details

Simulink Control Design™

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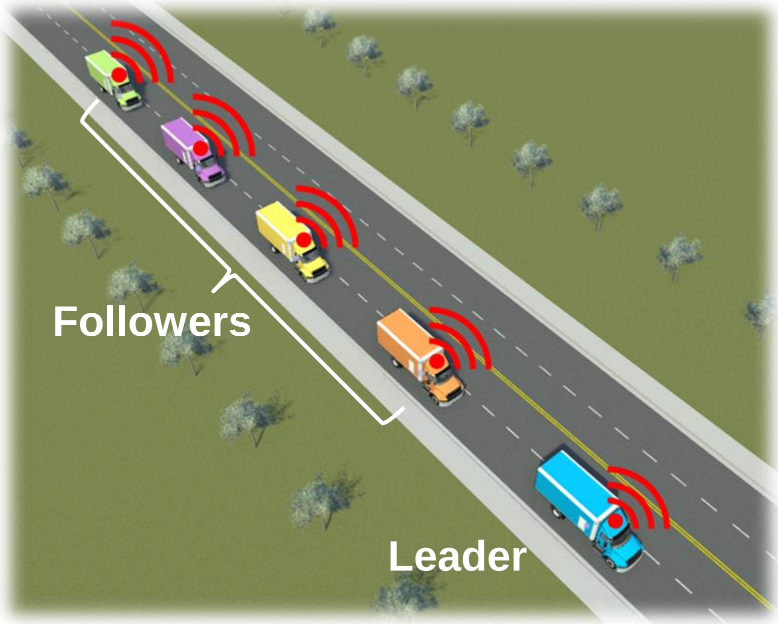
What is V2V? How does V2V work?

- **Vehicle-to-vehicle (V2V)** communication
  - enables vehicles to wirelessly exchange safety information of surrounding vehicles and provides the vehicles with a 360-degree awareness of other vehicles in proximity.

- **V2V communications** systems
  - use **dedicated short-range radio communication (DSRC) or cellular network**

    to exchange messages containing vehicle information (e.g., vehicle's speed, heading, braking status).



Basic Safety Message (BSM) by SAE J2735

SAE INTERNATIONAL

SURFACE VEHICLE STANDARD

J2735® | **JUL2020**

Issued 2006-12
Revised 2020-07

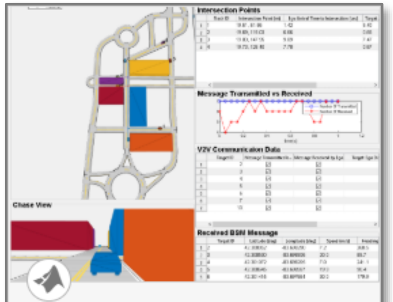
Superseding J2735 MAR2016

(R) V2X Communications Message Set Dictionary

- SAE J2735 – Data and message set dictionary
- Defines the **Basic Safety Message (BSM)**
  - Latitude, longitude, Elev
  - Speed
  - Heading angle
  - Steering wheel angle
  - Lat, long acceleration
  - Vehicle length, width

```
BSMcoreData ::= SEQUENCE {
  msgCnt          MsgCount,
  id              TemporaryID,
  secMark         DSecond,
  lat             Latitude,
  long            Longitude,
  elev            Elevation,
  accuracy        PositionalAccuracy,
  transmission    TransmissionState,
  speed           Speed,
  heading         Heading,
  angle           SteeringWheelAngle,
  accelSet        AccelerationSet4Way,
  brakes          BrakeSystemStatus,
  size            VehicleSize
  }
```

For more details



Intersection Movement Assist Using Vehicle-to-Vehicle Communication

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Open Example

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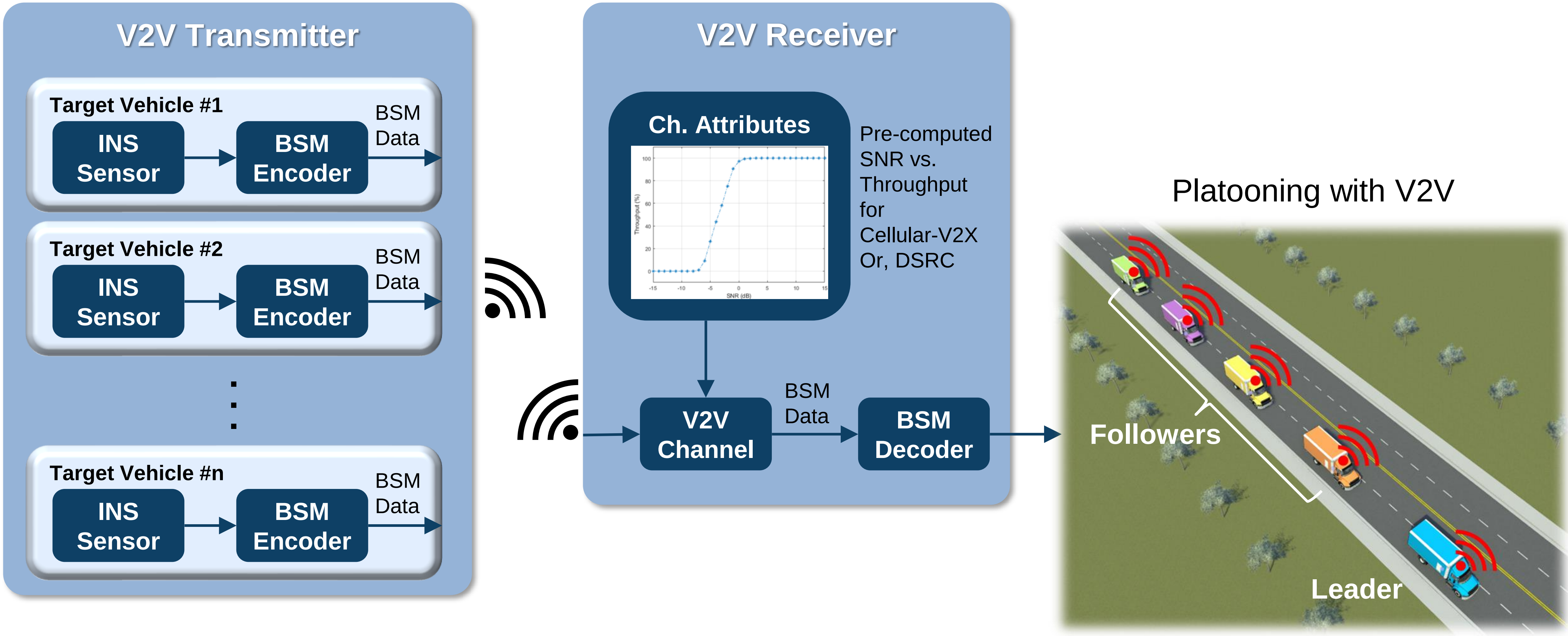
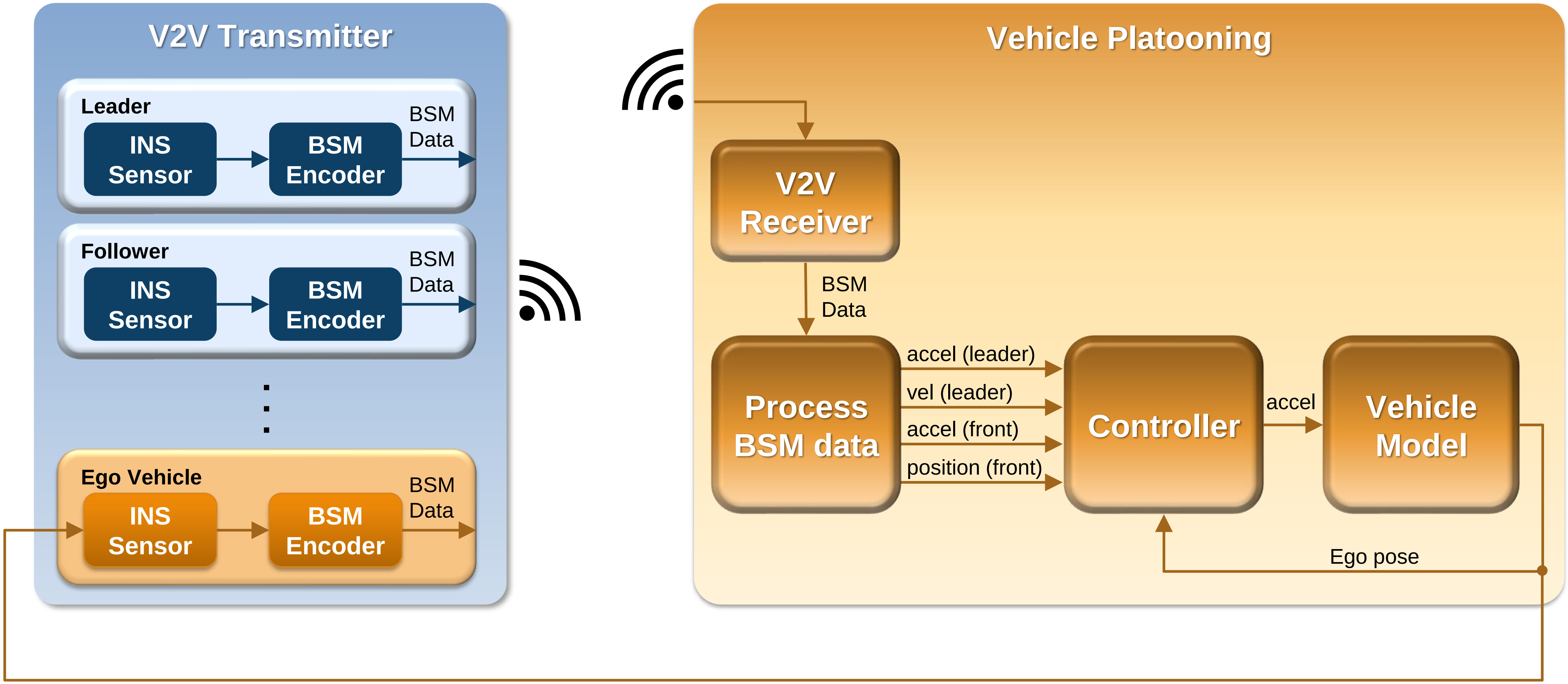
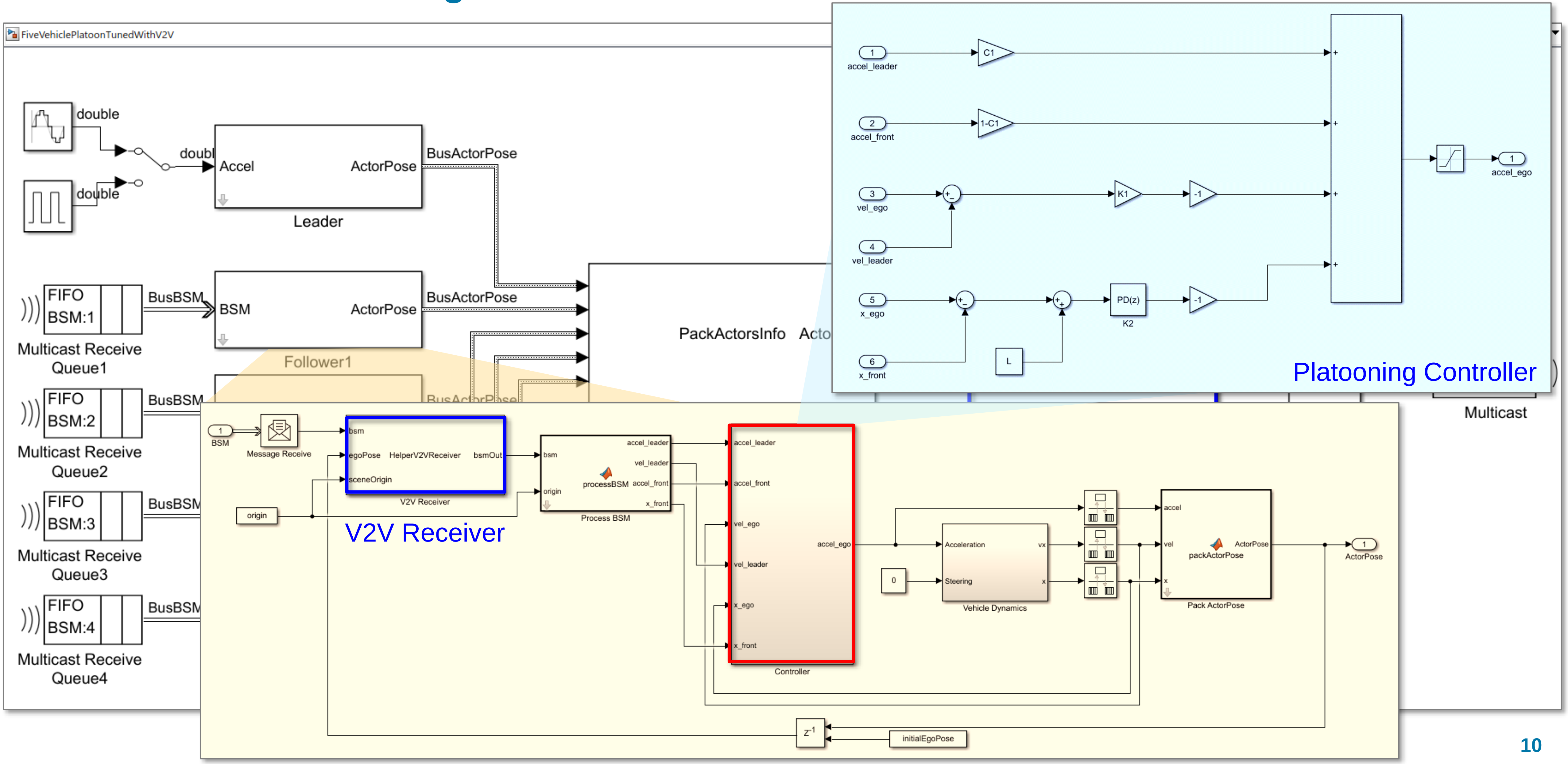
Design V2V Transmitter and Receiver



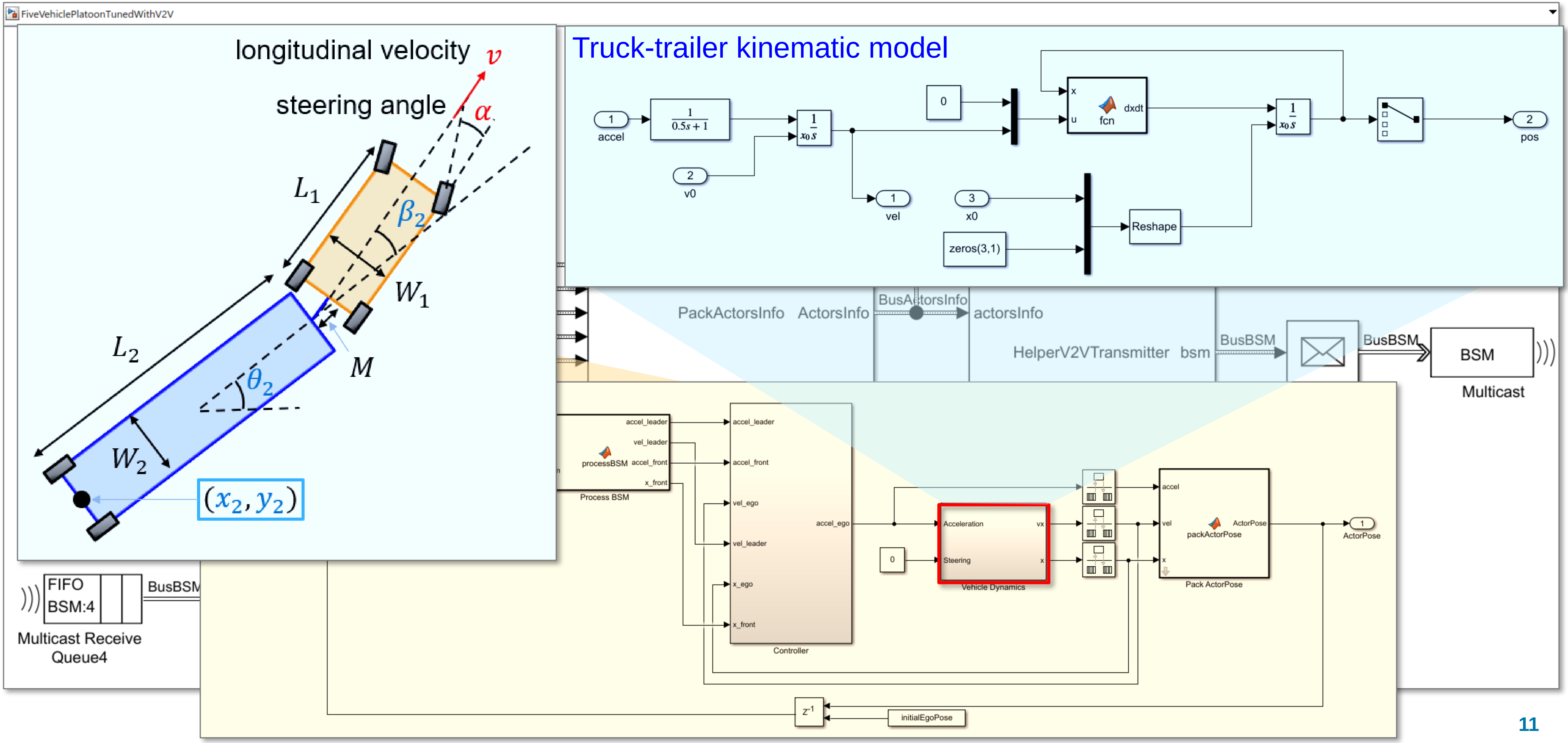
Vehicle Platooning Controller with V2V Communication



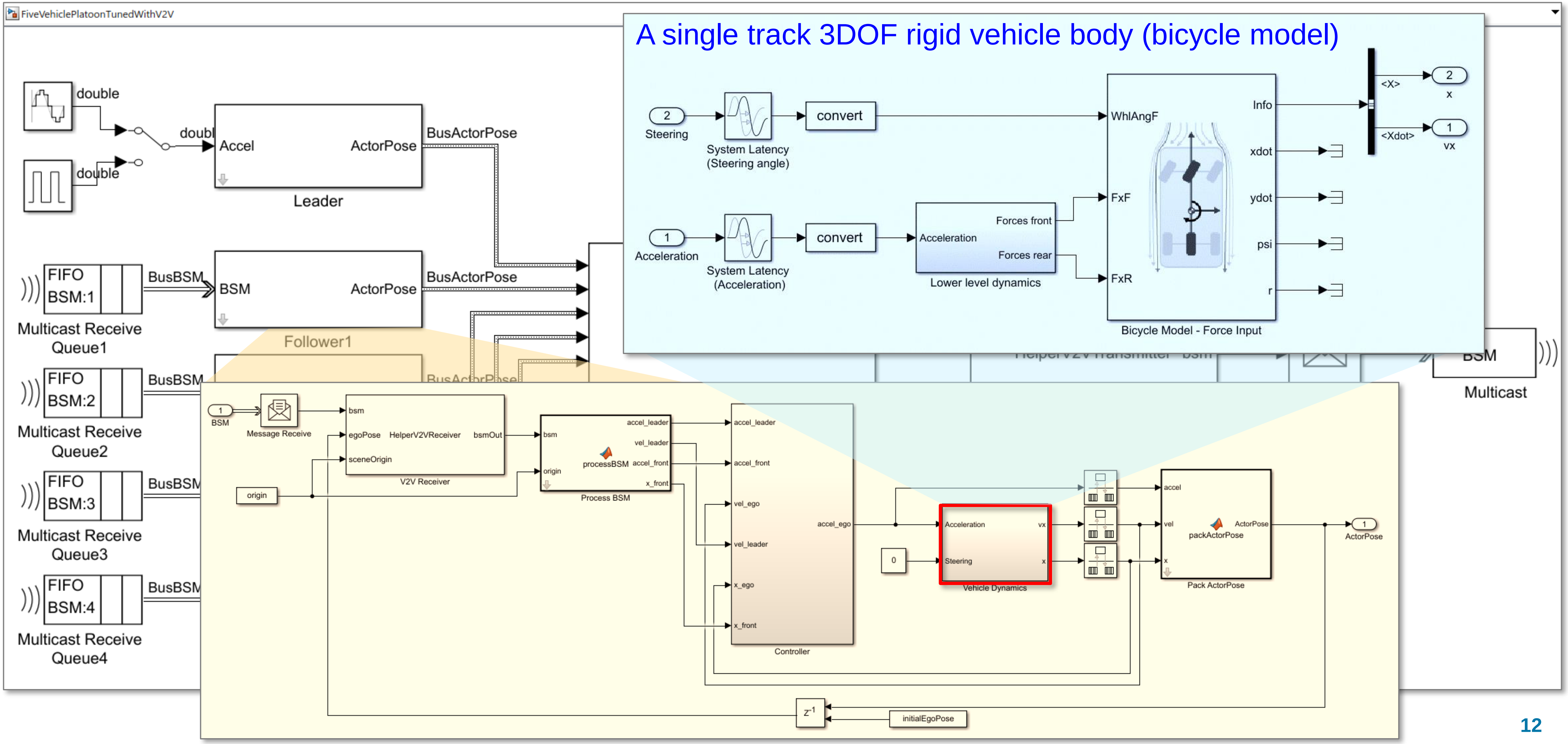
Vehicle Platooning Controller with V2V Communication



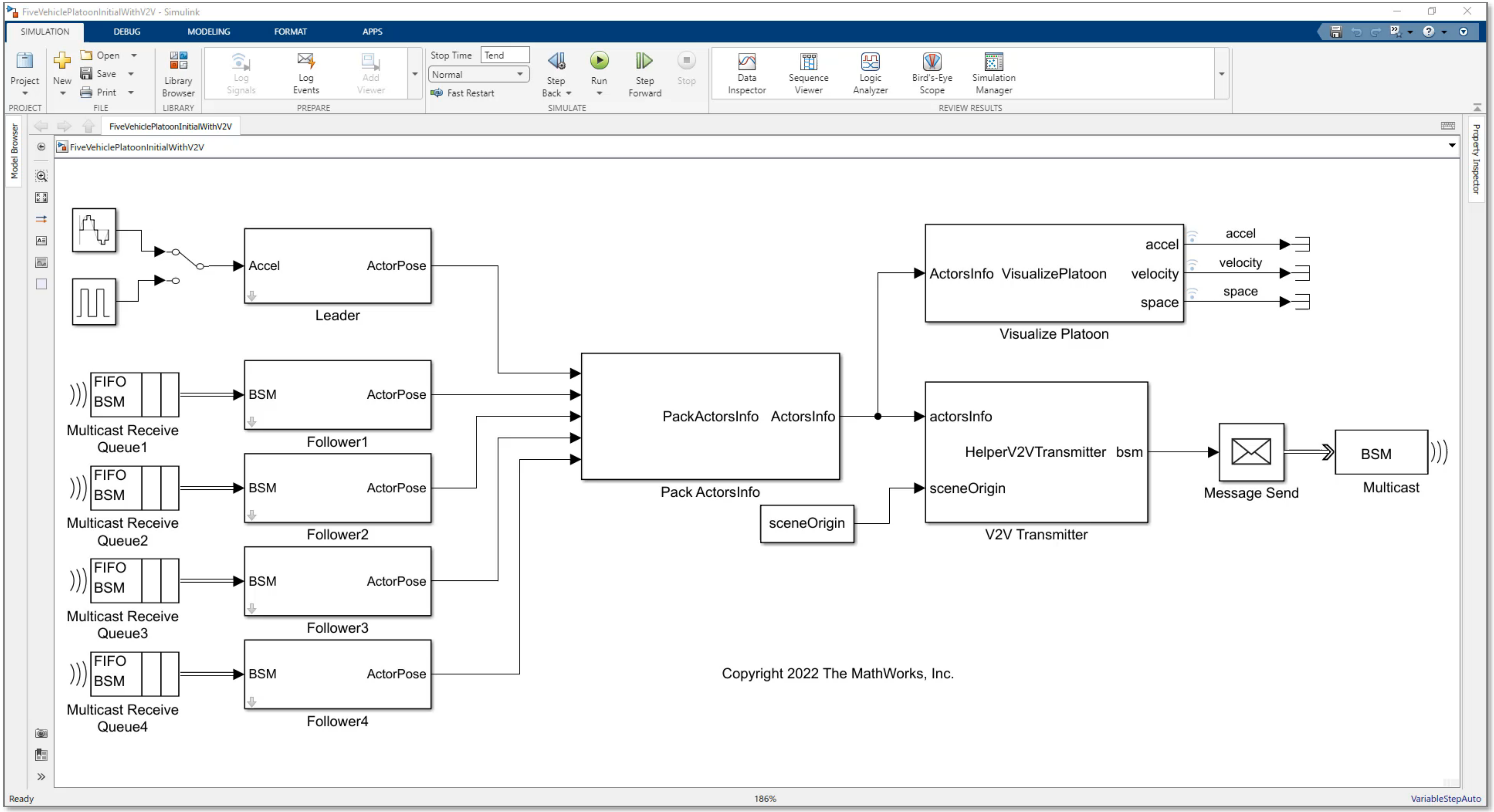
Vehicle Platooning Controller with V2V Communication



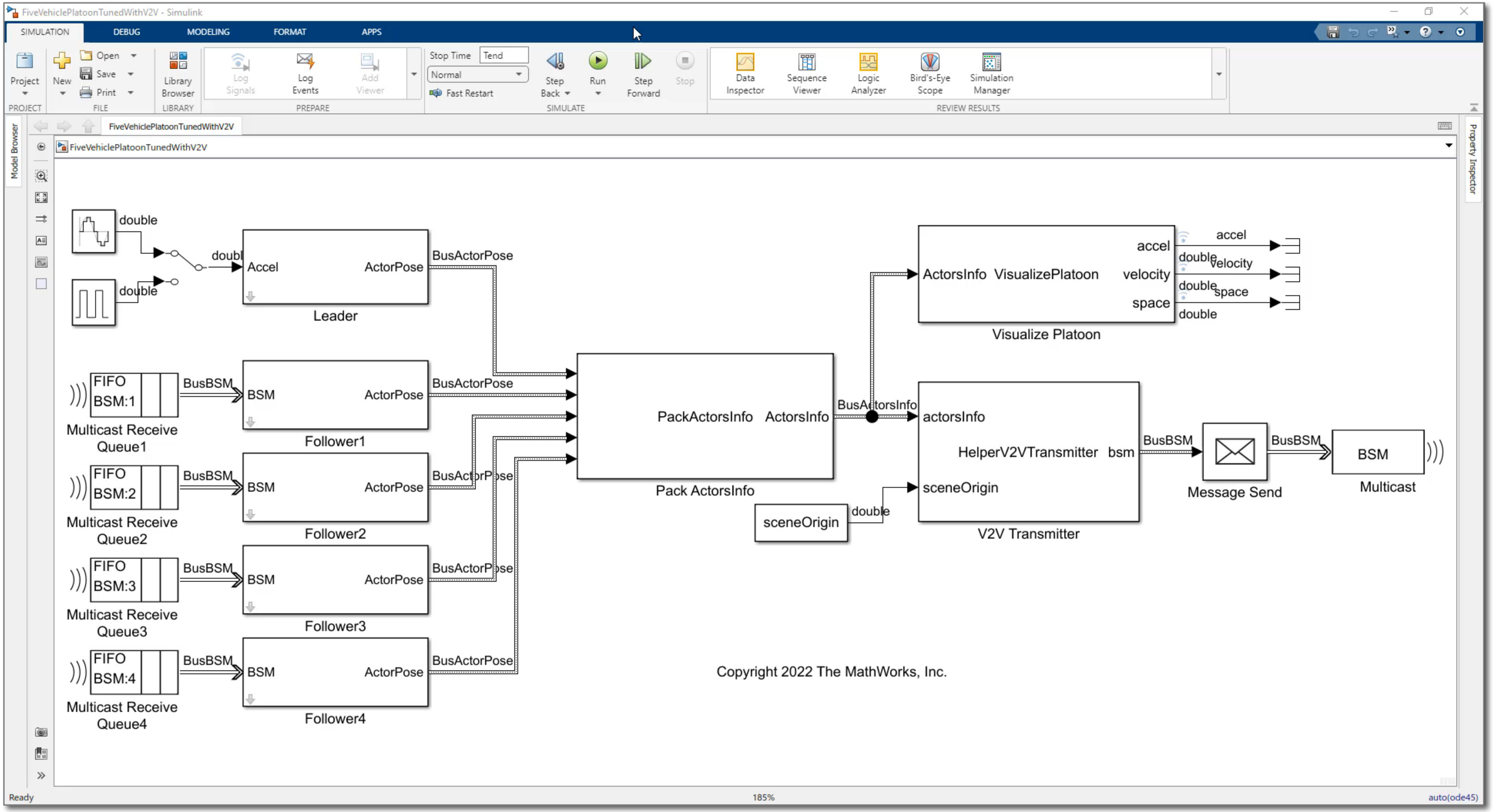
Vehicle Platooning Controller with V2V Communication



Simulation result (with initial setting of controller gains)

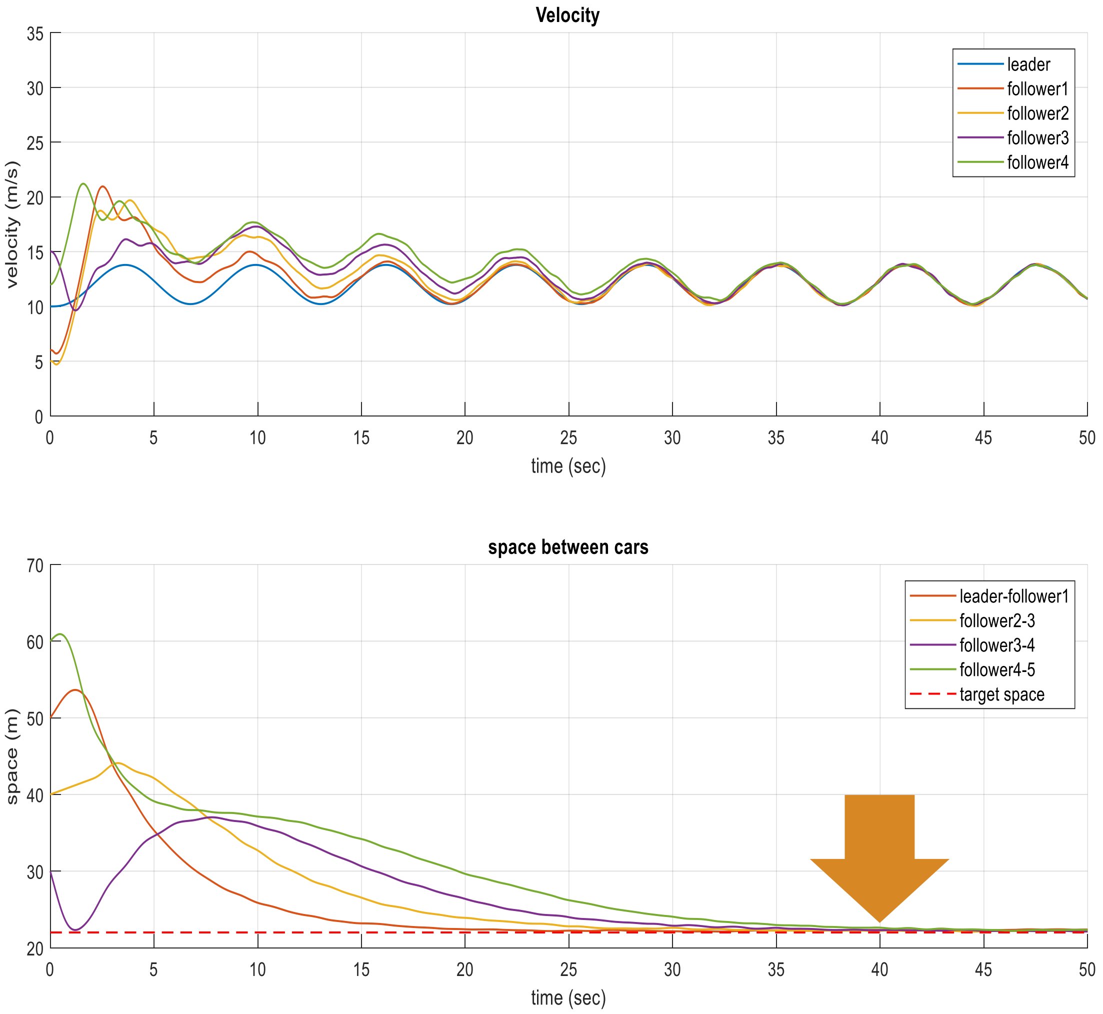


Simulation result (after tuning K2 for faster response)

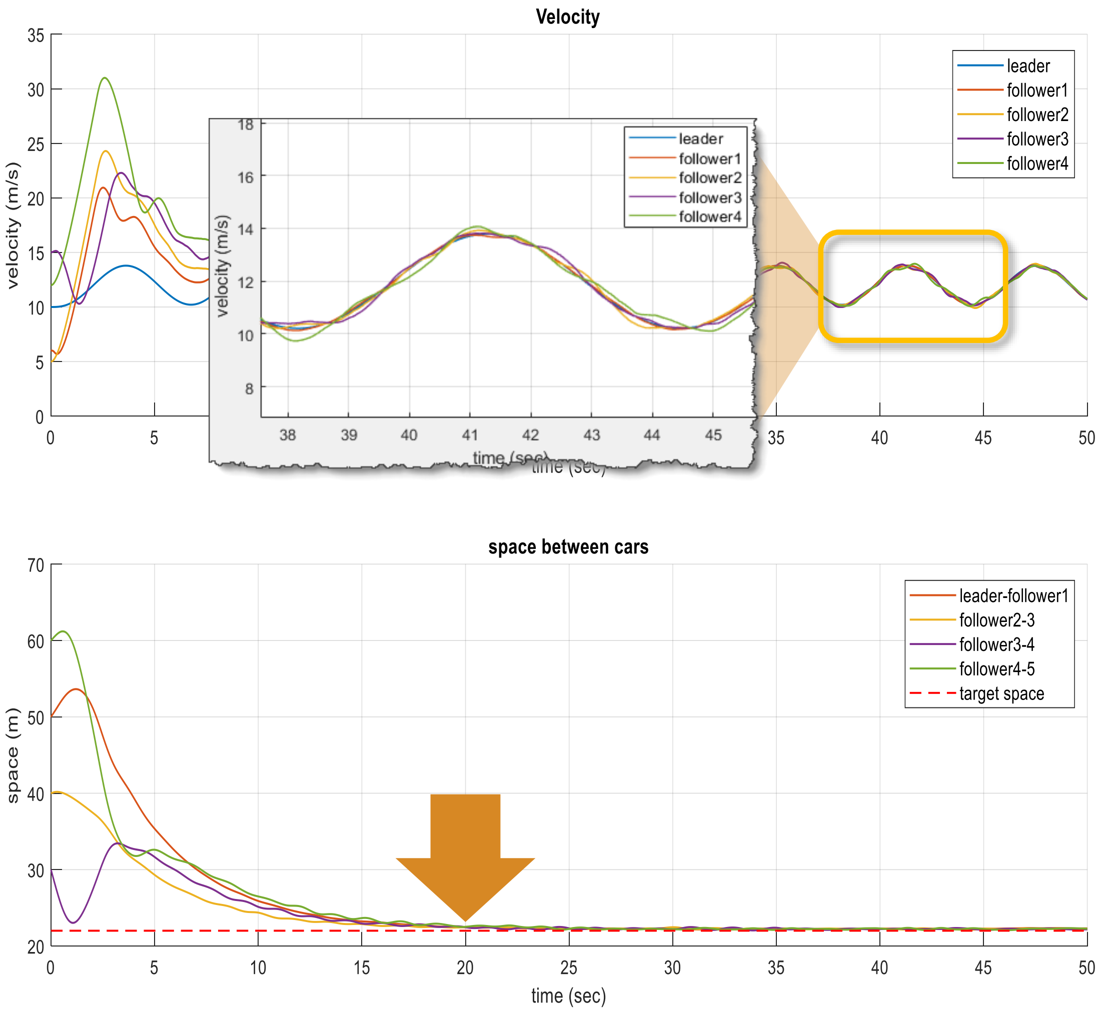


Simulation result (before vs. after tuning K2 for faster response)

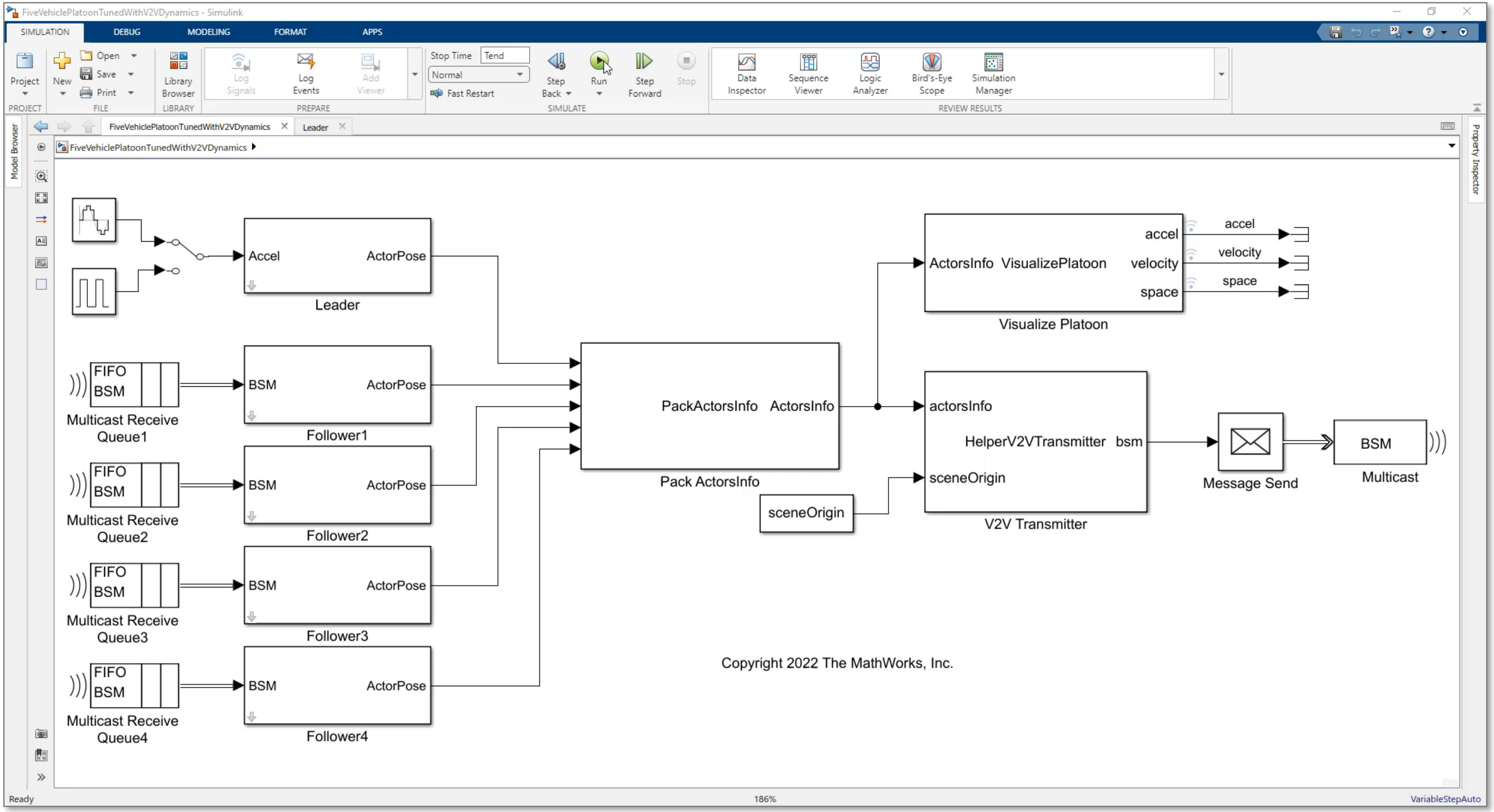
Before



After



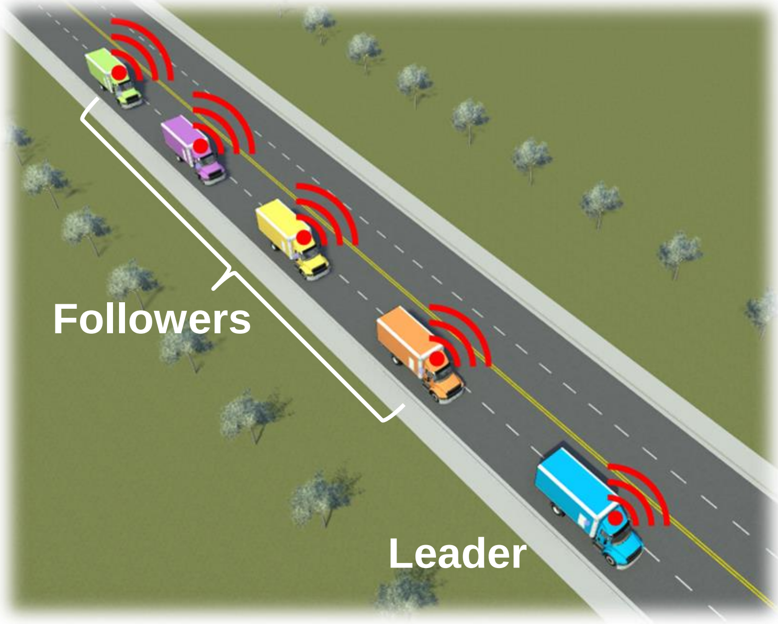
Simulation result (With a single track 3DOF rigid vehicle body - bicycle model)



Key takeaways:

Design of vehicle platooning controller with V2V communication

- Demonstrated how to design a controller for vehicle platooning controller with V2V communication using
  - Simulink Control Design™
  - Automated Driving Toolbox™
- The test bench model consists of
  - V2V communication
    - Model characteristics of the V2V communication channel
    - Implement BSM defined by SAE J2735
  - Vehicle model
    - Truck-trailer kinematic model
    - A single track 3DOF rigid vehicle body (bicycle model)
  - Distributed controller implementing sliding mode control



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Automated Driving Toolbox™

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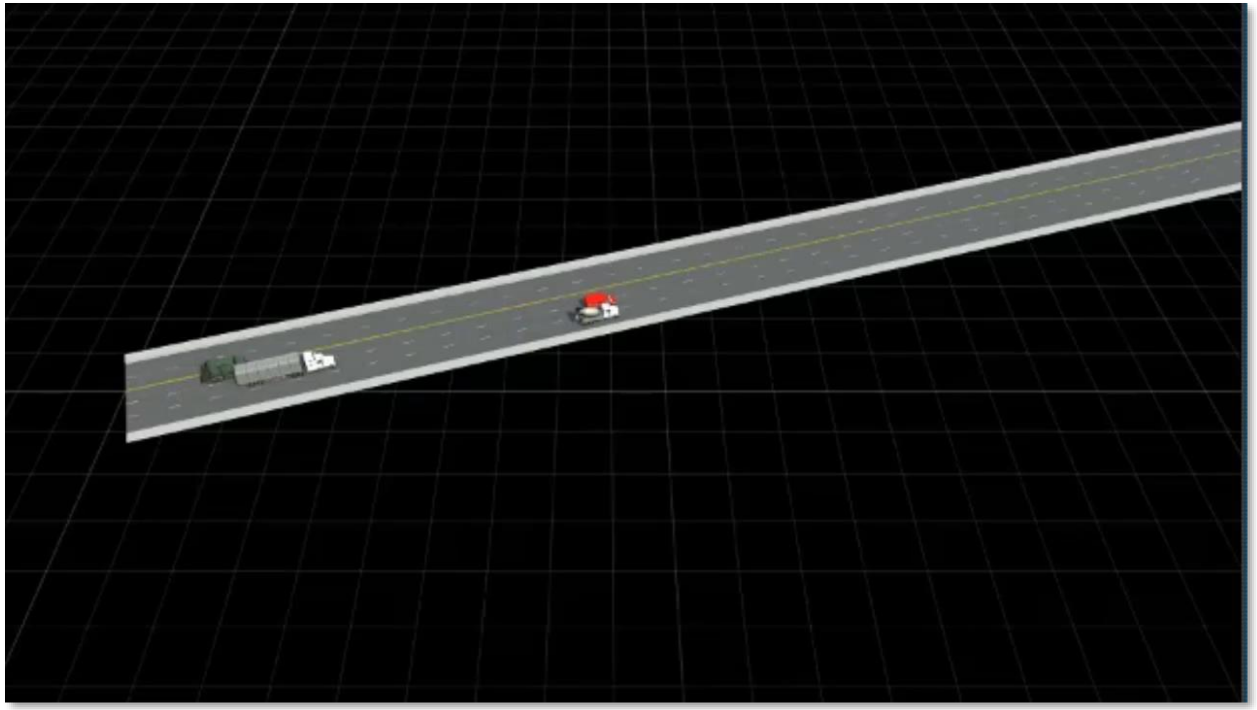
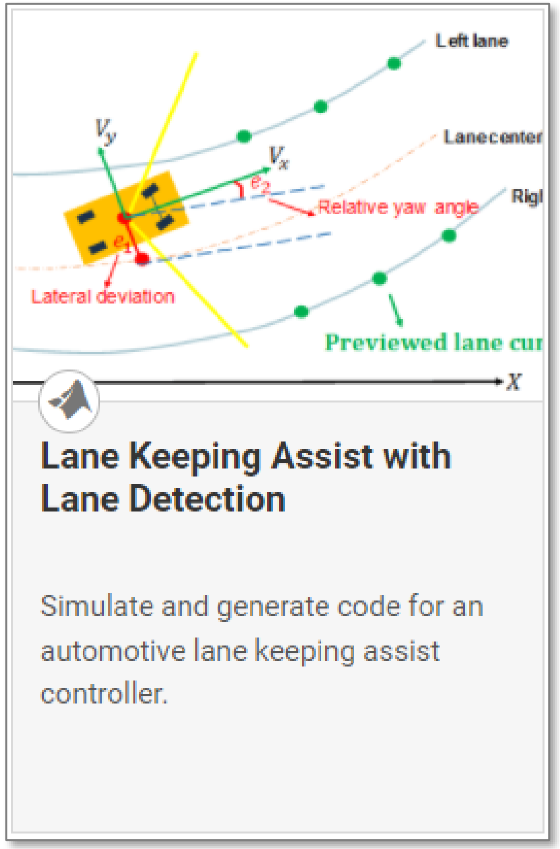
Further studies

- Scenario authoring using RoadRunner Scenario with truck and trailer meshes



- Platooning system requires a lateral control for curved roads.
  - Lateral control by Lane keeping control



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Thank you

Please contact me at spark@mathworks.com with questions

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