COOPERATIVE DRIVING

HW3

ECE 5553 – AUTONOMY IN VEHICLES

03/21/2018

THE OHIO STATE UNIVERSITY

CENTER FOR AUTOMOTIVE RESEARCH

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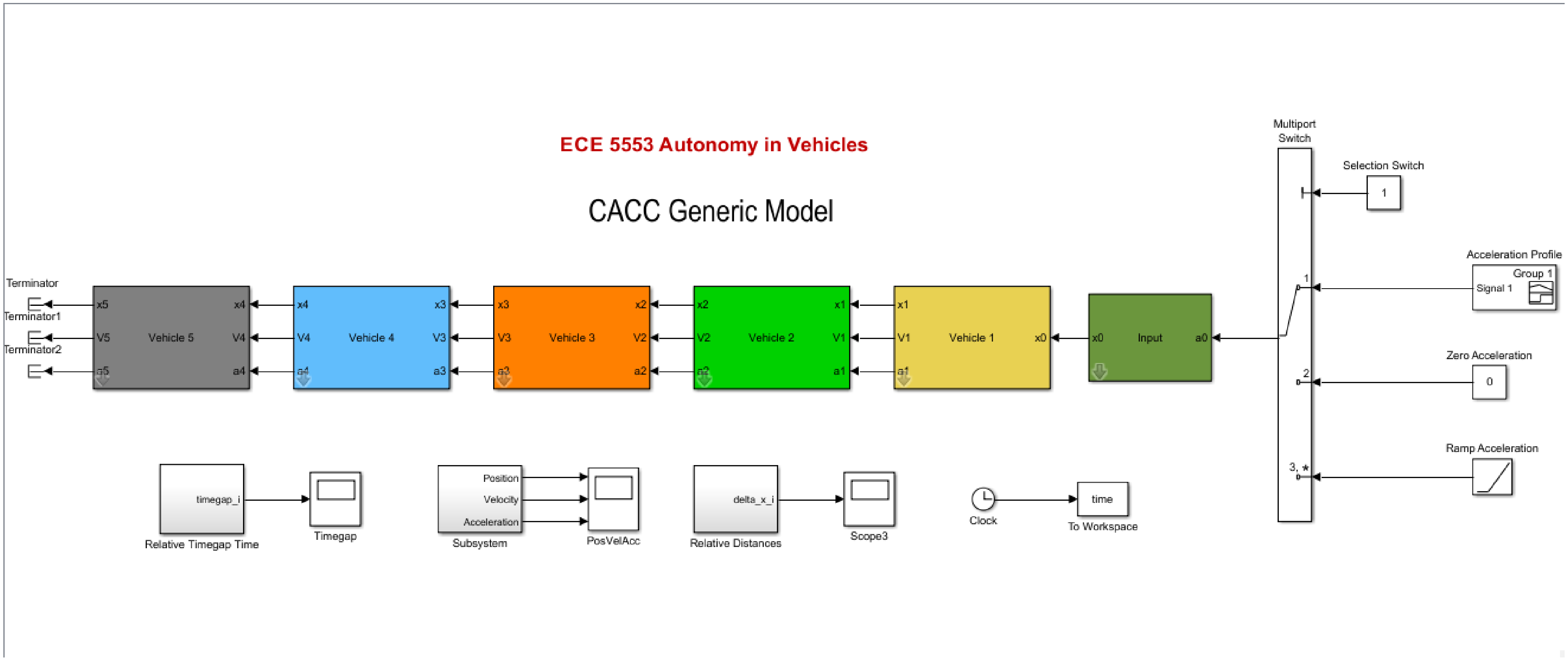
CACC/ACC SIMULATION

HOMOGENEOUS CONVOY

SIMULATION MODEL FOR THE CONVOY VEHICLES



PARAMETERS FOR THE CONVOY VEHICLES

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- Parameters :
  - Vehicle Model Gain(kG5, … kG1) = 1.0
  - Vehicle Time Constant (T5, … T1) = 0.7
  - Actuator (Internal) Delay (phi5, … phi1) [s] = 0.1
  - Communication System Delay (theta5, … theta2) [s] = 0.3
  - Headway time (hd5, … hd1) [s] = 0.6
  - Vehicle length (L5, … L1) [m] = 5
  - Distance at standstill (r5, ... r1) [m] = 30
  - Initial vehicle position (x5in) [m] = 0
    - (x4in) [m] =44 (x4in) [m] =50
    - (x3in) [m] =88 (x3in) [m] =100
    - (x2in) [m] =132 (x2in) [m] =150
    - (x1in) [m] =176 (x1in) [m] =200
  - Initial vehicle velocity (V5in, … V1in) [m/sec] = 15
  - CACC On/Off [0 or 1]
  - Controller Gain (wK5, … wK1) = 2.4
- Any parameters changed:
  - CCAC = 0 or CCAC =1
  - Change the initial vehicle velocity 25 m/s and change position by adding 50 m to vehicle 1 to 4 .

SIMULATION RESULTS TO QUESTIONS ASKED
HOMOGENOUS CONVOY - CACC

The vehicle time between all the vehicle is constant at 0.7s.

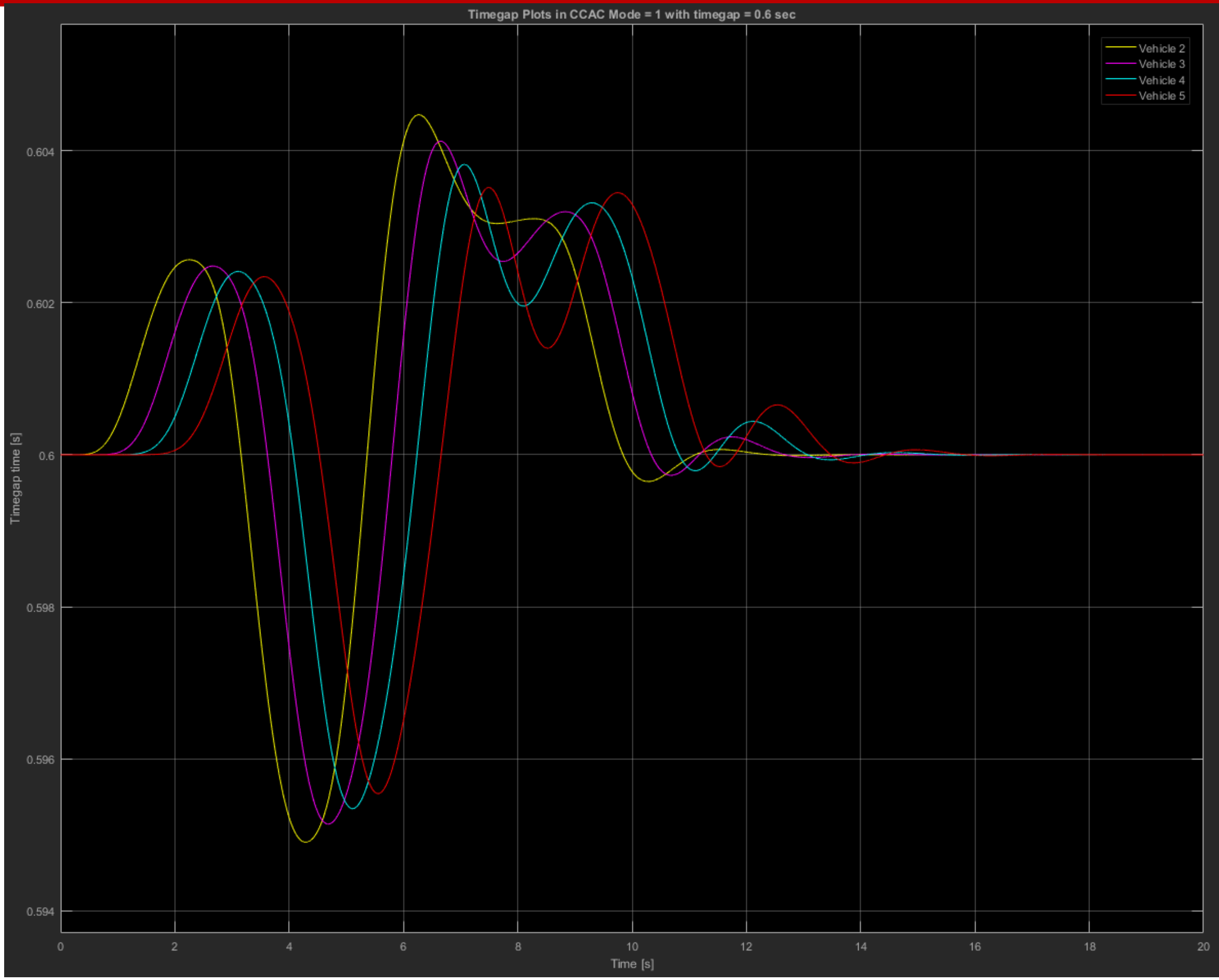
With CACC = 1 (on), vehicle 2 to 5 can be controlled to approximate the time gap to 0.6 sec as time goes to infinity.

According to the plot, it takes 16 sec to let vehicle 2 -5 have the same time gap.

There are some overshooting and undershooting, but the magnitude of the oscillation is reducing.

Vehicle 2 has the highest oscillation magnitude before 8 second but the fastest to be settle down.

In opposite, vehicle 5 has the lowest oscillation magnitude before 8 second but the longest time to be settle down.



SIMULATION RESULTS TO QUESTIONS ASKED
HOMOGENOUS CONVOY - CACC

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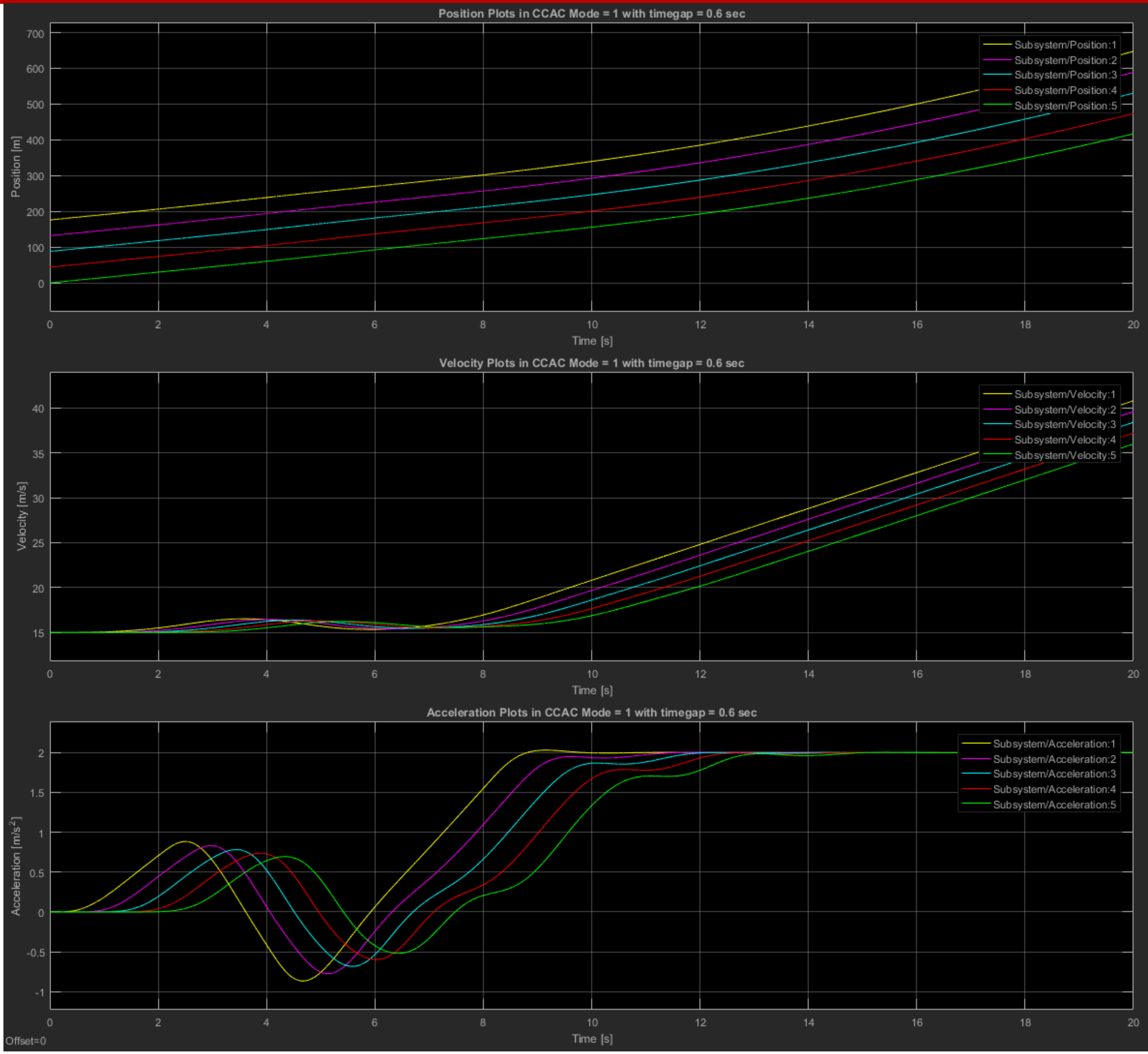
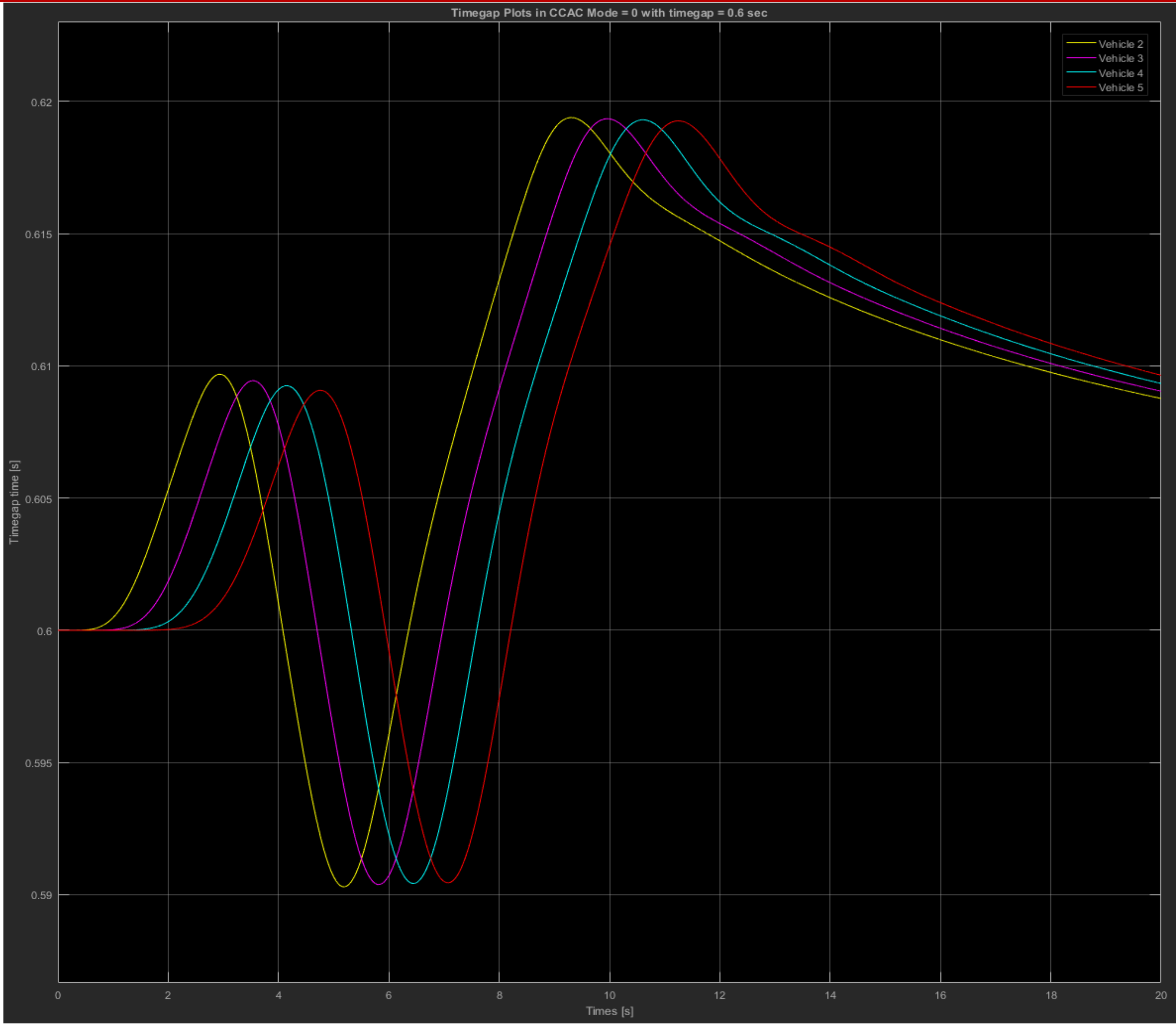
- The vehicle time between all the vehicle is constant at 0.7s.
- With CACC = 1 (on), vehicle 2 to 5 can be controlled to follow the lead car in the same path as shown in Positon plot.
- The acceleration of all the car keep at 2 m/s^2. It turns out that all of the vehicle has the same speed.



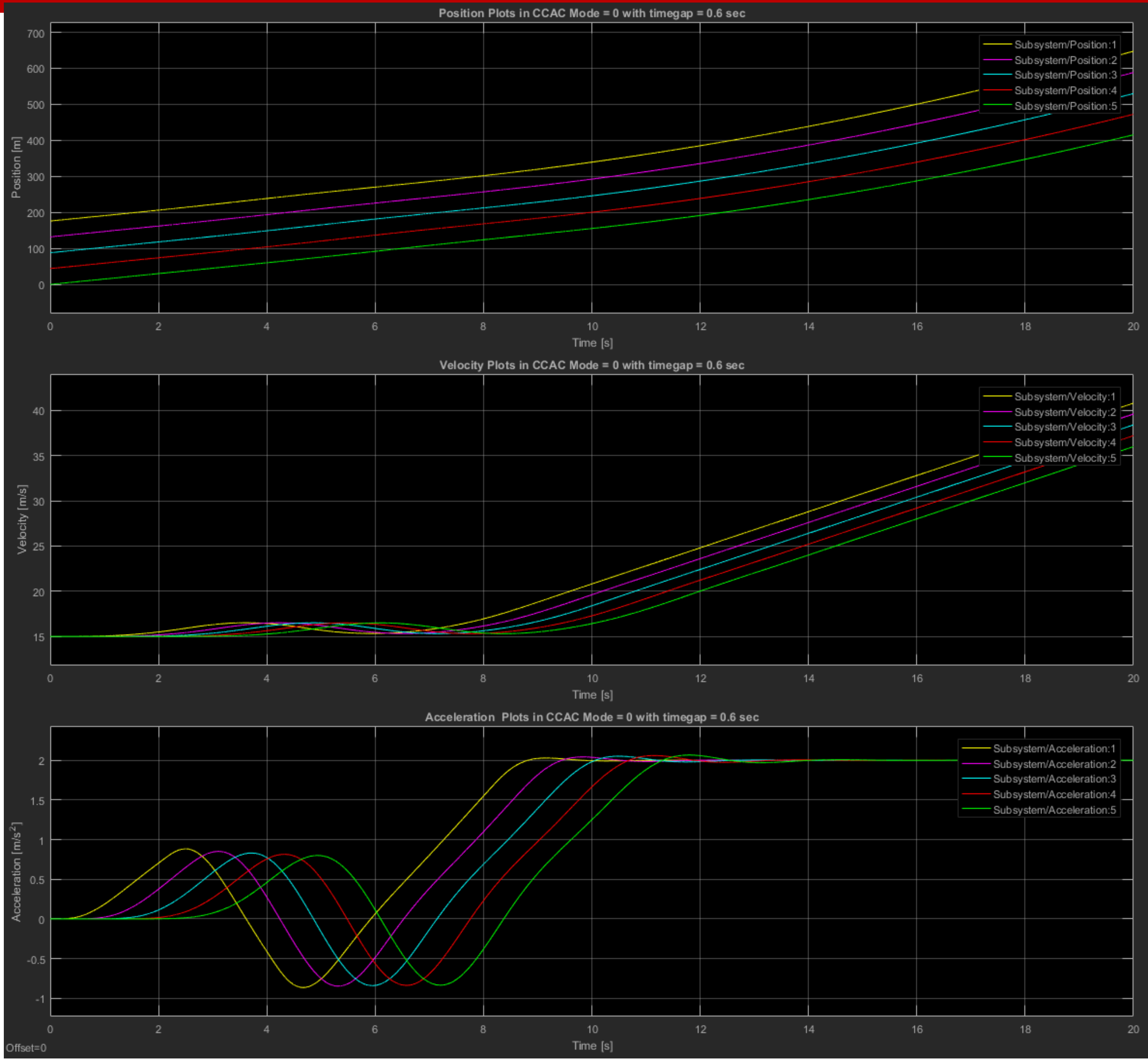
SIMULATION RESULTS TO QUESTIONS ASKED
HOMOGENOUS CONVOY - ACC

- The vehicle time between all the vehicle is constant at 0.7s.
- With CACC = 0 (off), vehicle 2 to 5 cannot be controlled to approximate the time gap to 0.6 sec as time goes to infinity.
- Time gap is about 0.608, which is approximately 0.1 sec away from the desire time gap.
- Oscillatory response of the convoy with very poor time gap regulation in the ACC case.



SIMULATION RESULTS TO QUESTIONS ASKED
HOMOGENOUS CONVOY - ACC

- The vehicle time between all the vehicle is constant at 0.7s.
- ACC can do the same job to controlled the acceleration of vehicle 2 to5, but the rate of acceleration is large.
- (2-(-0.5))/2 =1.25 m/s^3
- The rate of acceleration under 1 can be consider as a comfort driving.
- The acceleration oscillations in acceleration plot shows that ACC also has poor drivability characteristics as compared to CACC.
- As a result the velocity changed variously than velocity of CACC Model.

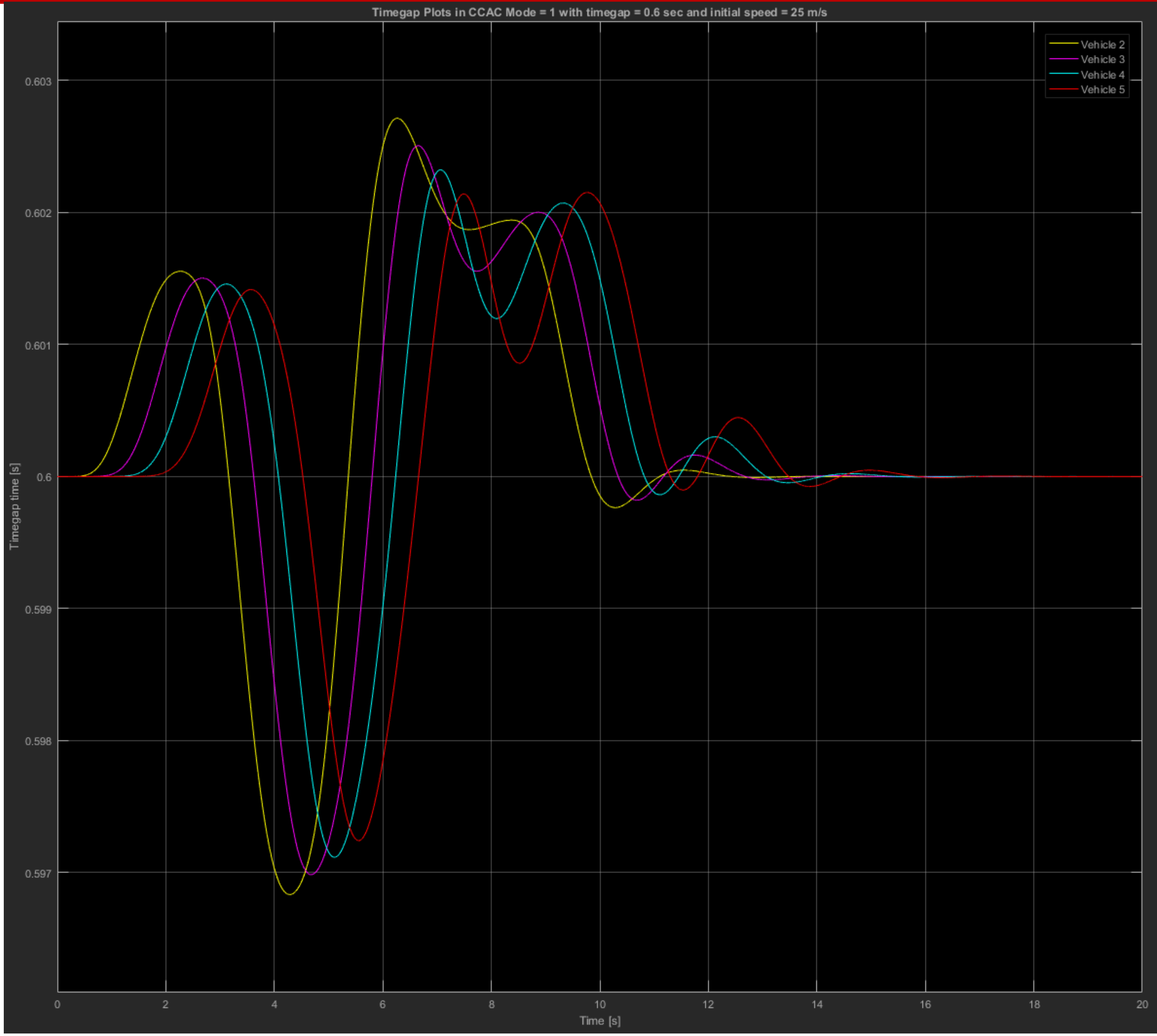


INITIAL CONDITION DETERMINATION

- Initial vehicle position = initial vehicle velocity * headway time + distance at standstill + vehicle length
- = 25 m/s * 0.6 s + 30 m + 5 m
- =15 m +30 m + 5 m
- =50 m

SIMULATION RESULTS TO QUESTIONS ASKED
HOMOGENOUS CONVOY – CACC WITH 25 M/S

- The vehicle time between all the vehicle is constant at 0.7s.
- CACC works better in a high speed condition.
- The oscillation magnitude (overshoot & undershoot)of all the vehicles are smaller as compare to the CACC model in 15 m/s case.
- From the plot, it still takes 16 sec to completely settle down all vehicles form 2 to 5.



SIMULATION RESULTS TO QUESTIONS ASKED
HOMOGENOUS CONVOY – CACC WITH 25 M/S

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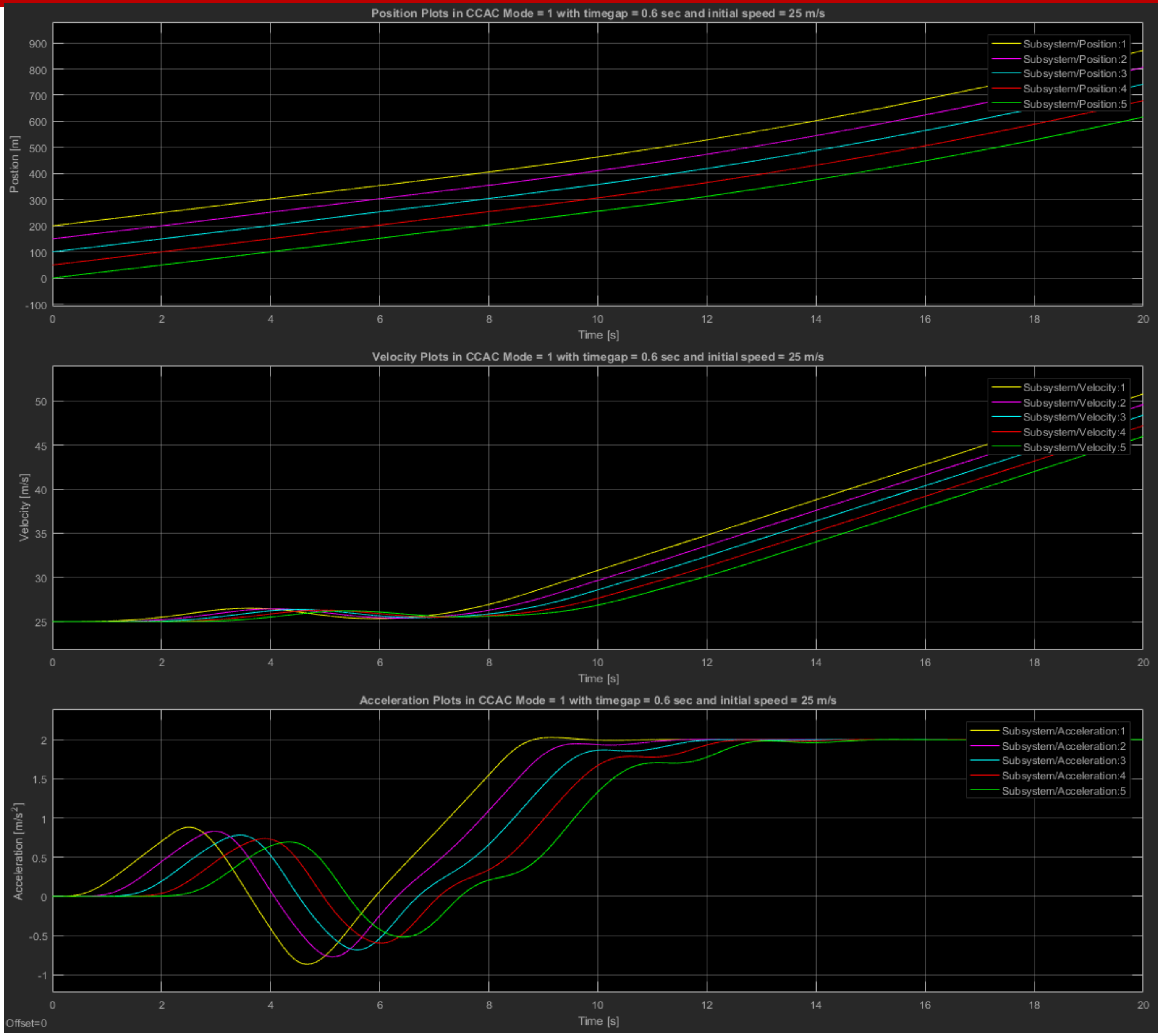
- CACC has a better performance in high speed.
- It still takes 16 second to make all vehicle have same acceleration.



SIMULATION RESULTS TO QUESTIONS ASKED
HOMOGENOUS CONVOY – ACC WITH 25 M/S

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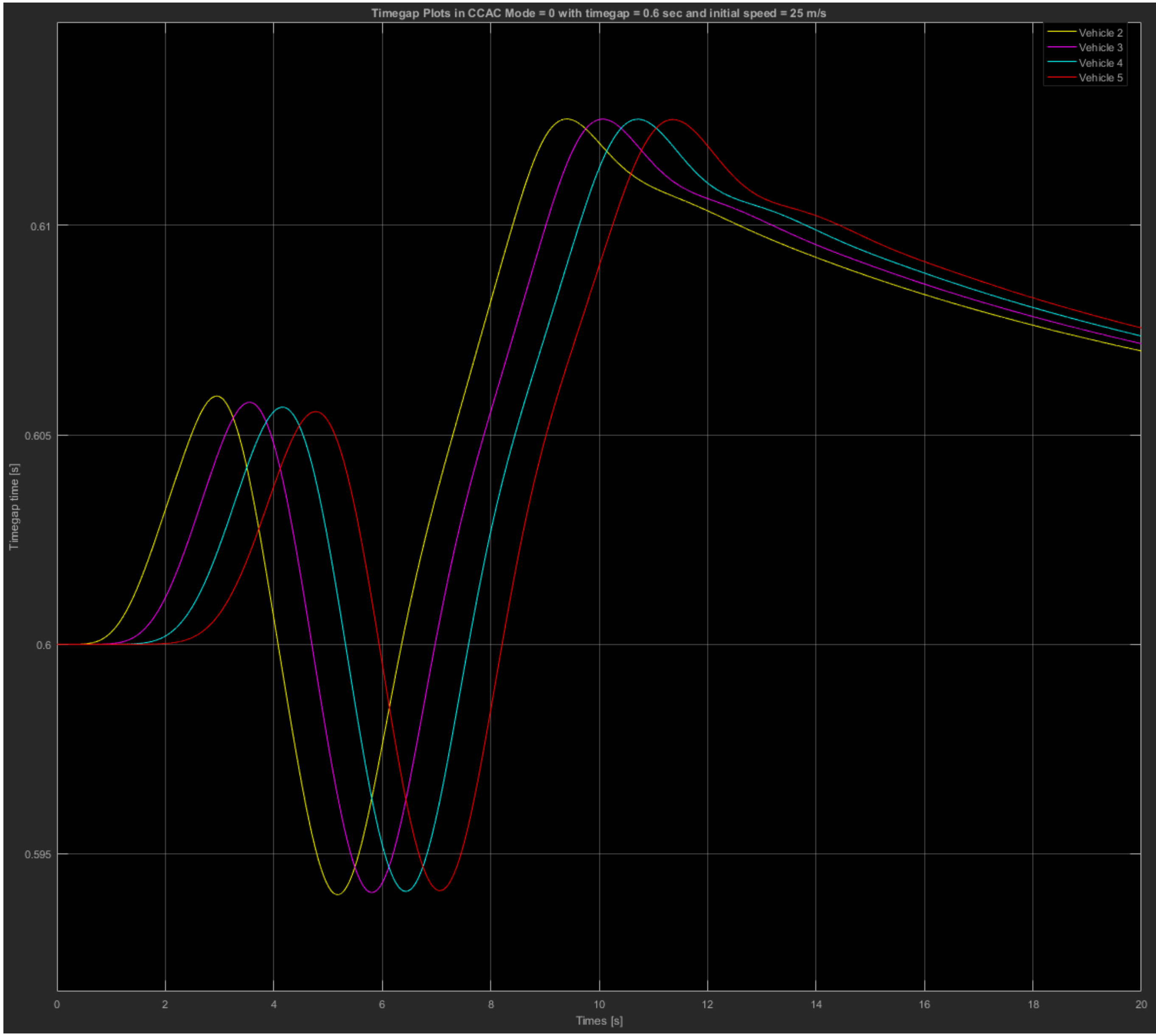
- ACC also have a better performance at high speed (25 m/s)
- The oscillation magnitude (overshoot & undershoot)of all the vehicles are smaller as compare to the ACC model in 15 m/s case.
- Although the time gap is reduced as time goes to infinity, it doesn't fix the problem that it still have very poor time gap regulation in the ACC case



SIMULATION RESULTS TO QUESTIONS ASKED

HOMOGENOUS CONVOY – ACC WITH 25 M/S

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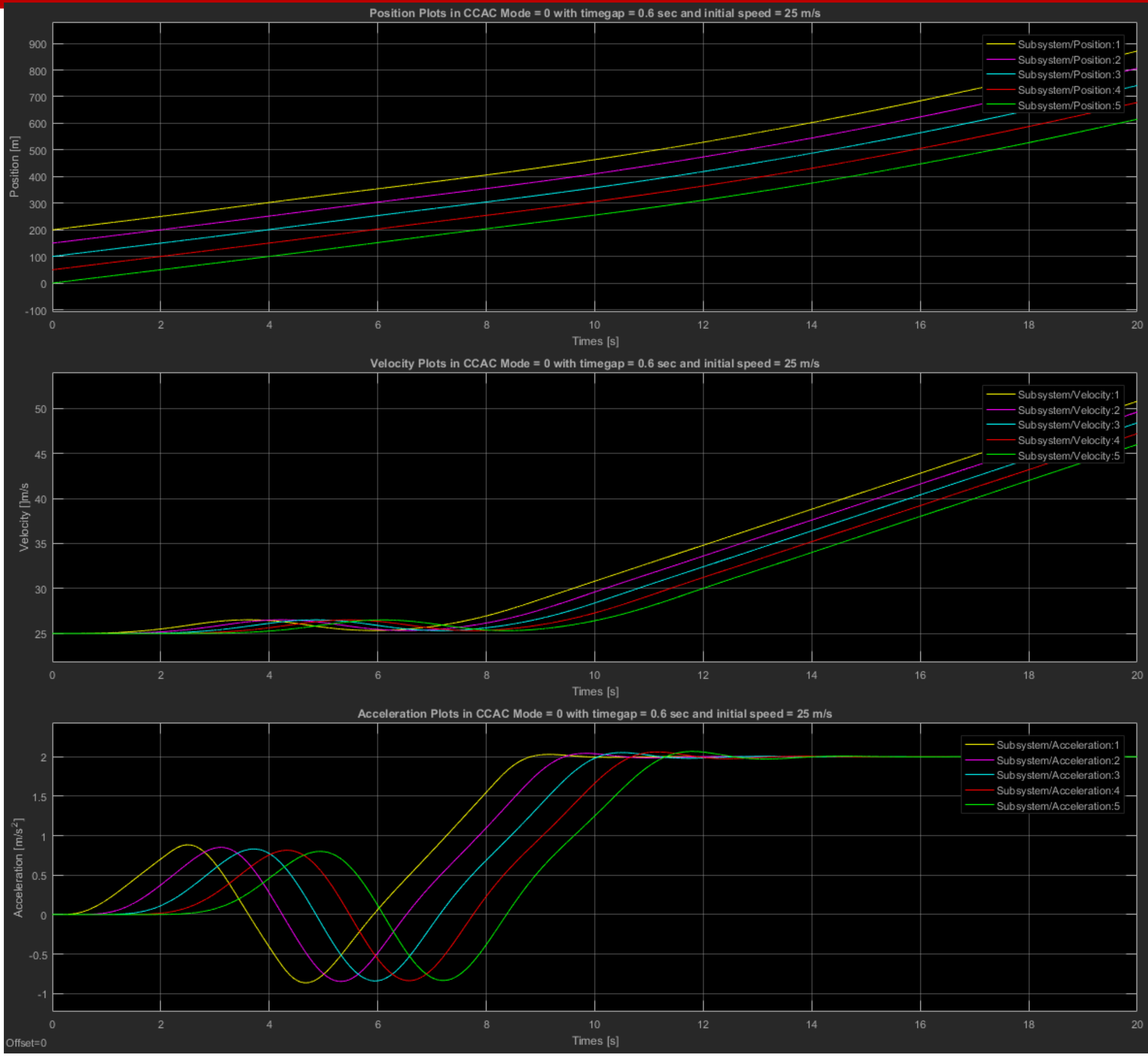
- ACC is able to do the same control job in high speed as well.
- Although ACC have better performance in high speed, the acceleration oscillations in acceleration plot shows that ACC also has poor drivability characteristics as compared to CACC.



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CACC/ACC SIMULATION

HETEROGENEOUS CONVOY

PARAMETERS FOR THE CONVOY VEHICLES
HETEROGENEOUS CONVOY

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- Parameters :
    - Vehicle Model Gain(kG5, … kG1) = 1.0
    - Vehicle Time Constant (T5) = 0.7
        - (T4) = 0.35
        - (T3) = 0.6
        - (T2) = 0.4
        - (T1) = 0.3
    - Actuator (Internal) Delay (phi5, … phi1) [s] = 0.1
    - Communication System Delay (theta5, … theta2) [s] = 0.3
    - Headway time (hd5, … hd1) [s] = 0.6
    - Vehicle length (L5, … L1) [m] = 5
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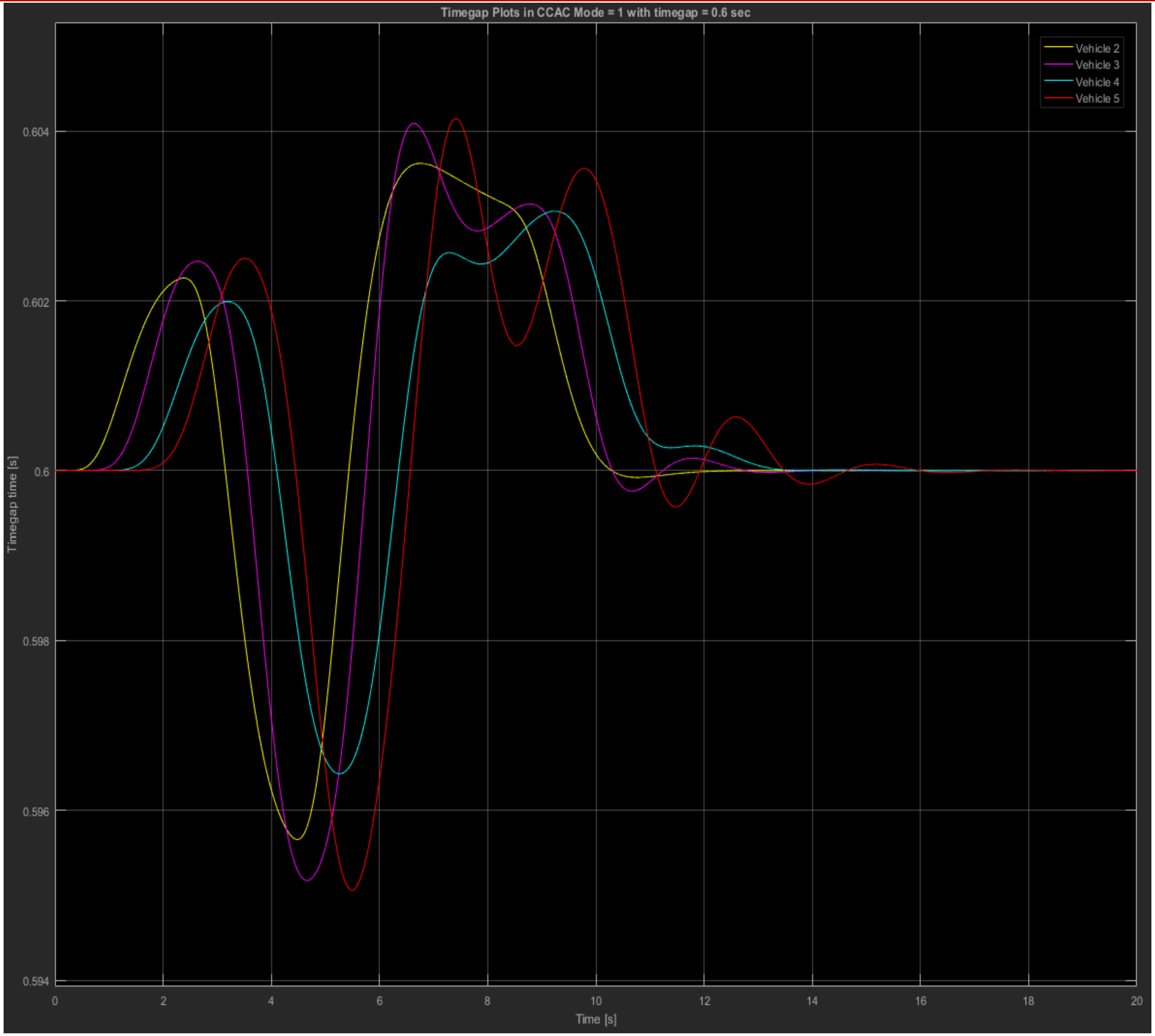
    - Initial vehicle velocity (V5in, … V1in) [m/sec] = 15
    - CACC On/Off [0 or 1]
    - Controller Gain (wK5, … wK1) = 2.4
- Any parameters changed:
    - CCAC = 0 or CCAC =1

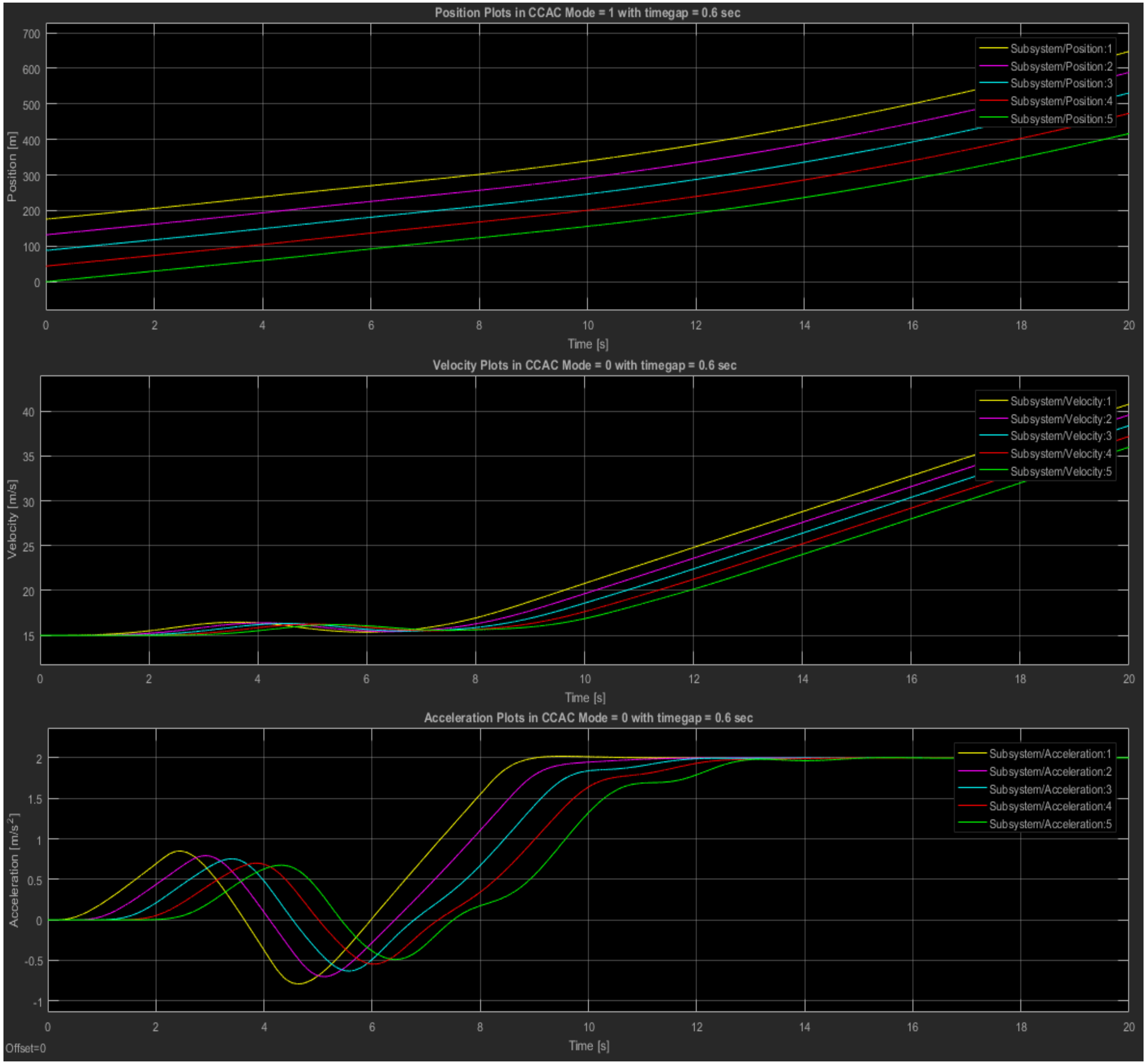
SIMULATION RESULTS TO QUESTIONS ASKED
HETEROGENEOUS CONVOY - CACC

- Since the vehicle time constant has been changed for each vehicle from 2 to 5 .
- It creates more difficulty for CACC model to control path following.
- Vehicle 2 is the first one to be settle down, then vehicle 3,4,5
- In heterogeneous convoy, CACC control vehicle 2 -5 to have the same time gap within 16 seconds.



SIMULATION RESULTS TO QUESTIONS ASKED
HETEROGENEOUS CONVOY - CACC

- In CACC, the oscillation amplitude of vehicle 2 to 5 doesn't change rigorously as compare to the homogeneous convoy.
- With CACC = 1 (on), vehicle 2 to 5 can be controlled to follow the lead car in the same path as shown in Positon plot.
- The acceleration of all the car keep at 2 m/s^2. It turns out that all of the vehicle has the same speed.
- It still takes 16 second to make all vehicle have same acceleration.



SIMULATION RESULTS TO QUESTIONS ASKED
HETEROGENEOUS CONVOY - ACC

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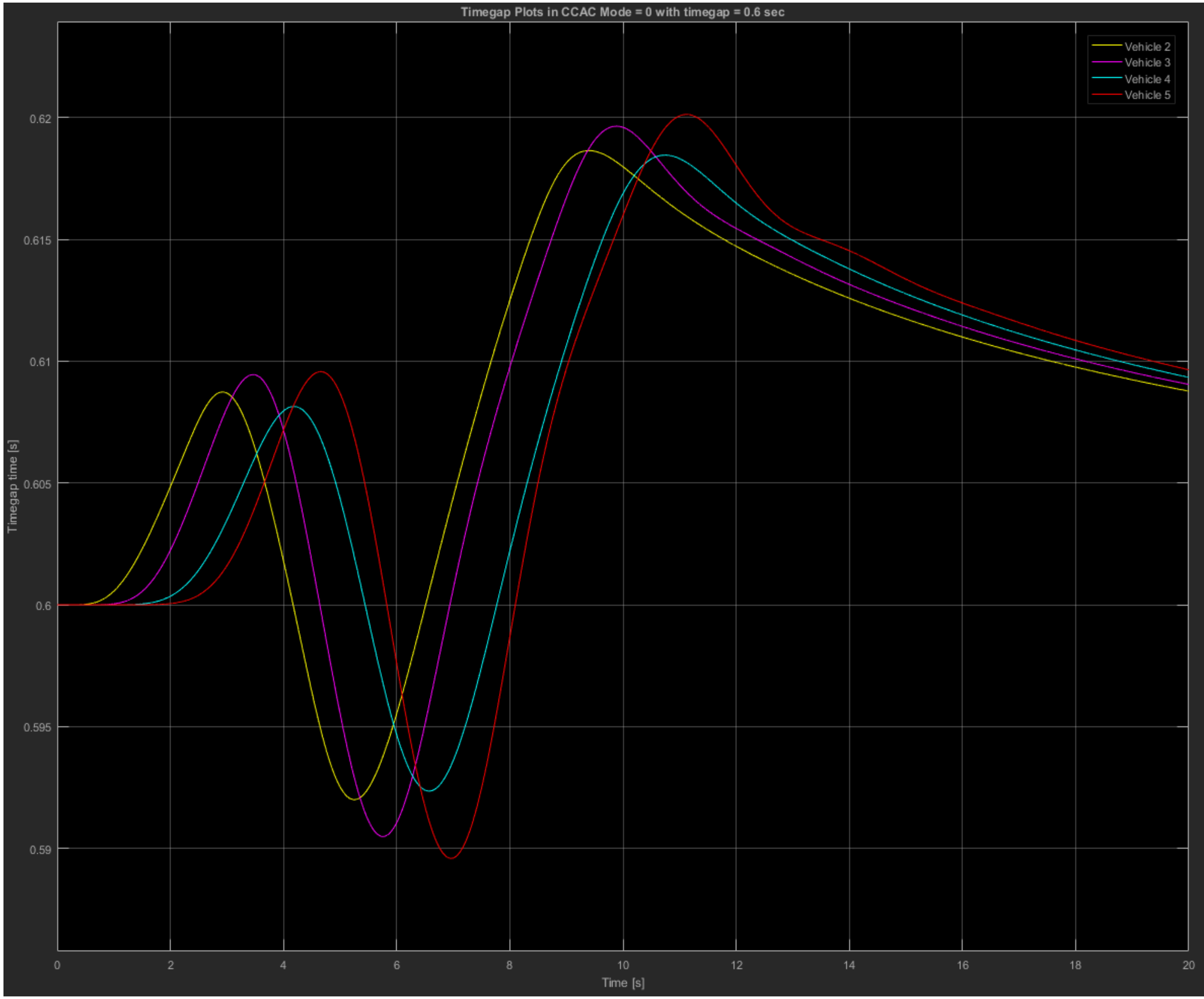
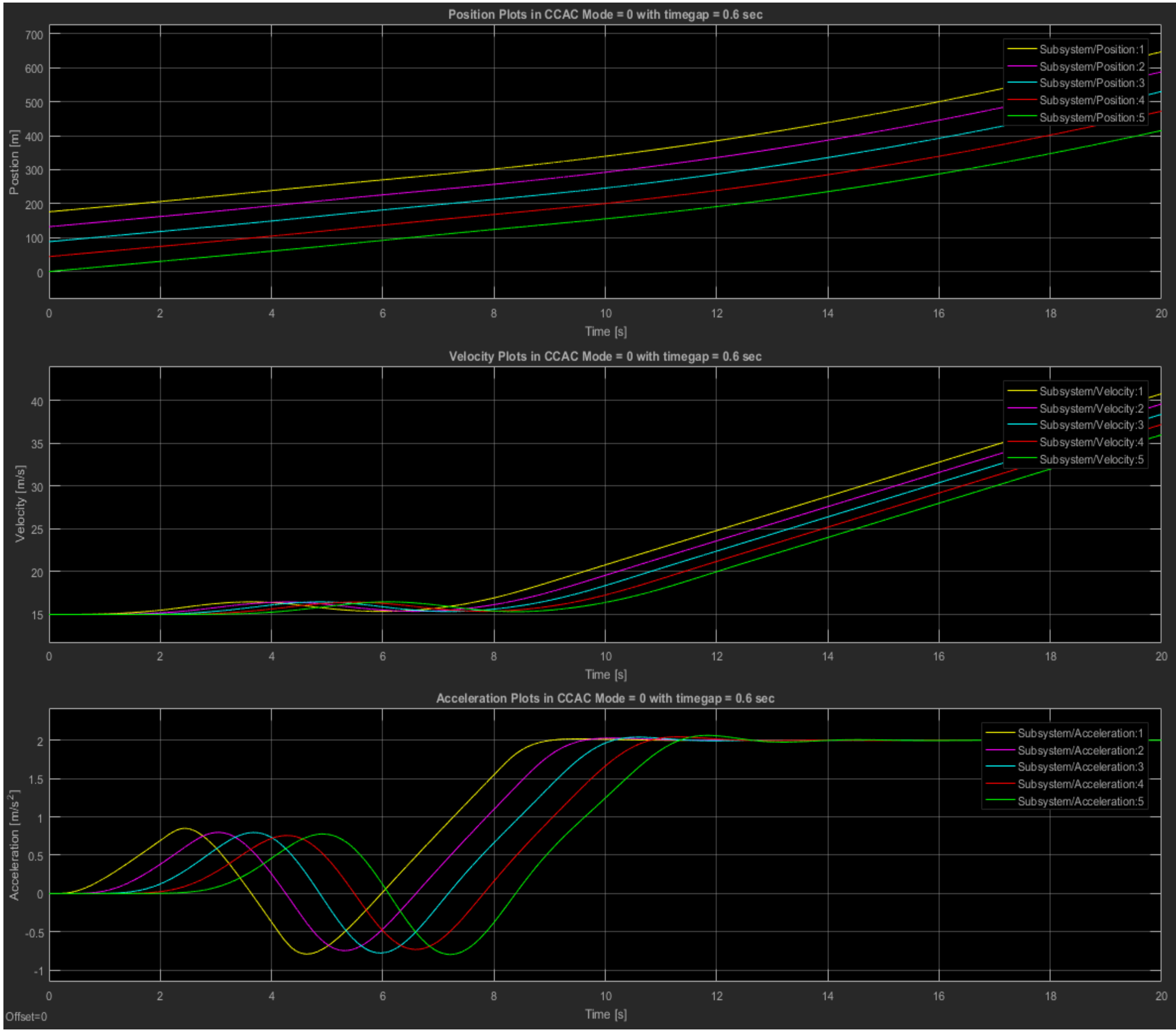
- Since the vehicle time constant has been changed for each vehicle from 2 to 5 .
- It creates more difficulty for ACC model to control path following.
- Time gap is about 0.608, which is approximately 0.1 sec away from the desire time gap.
- Oscillatory response of the convoy with very poor time gap regulation in the ACC case.



SIMULATION RESULTS TO QUESTIONS ASKED
HETEROGENEOUS CONVOY - ACC

- ACC is able to do the same control job in heterogeneous convoy as well.
- Although ACC have better performance in high speed, the acceleration oscillations in acceleration plot shows that ACC also has poor drivability characteristics as compared to CACC.
- It still takes 16 second to make all vehicle have same acceleration.



STRING STABILITY

HETEROGENEOUS CONVOY

- Derivation of the String stability for CACC & ACC

- CACC

$$E_i(s) = X_{i-1}(s) - H(s) \cdot X_i(s)$$

$$X_i(s) = G_i(s) \cdot [Cff_i(s) \cdot e^{-\beta s} \cdot s^2 X_{i-1} + Cfb_i(s) \cdot E_i(s)]$$

$$= G_i(s) \cdot \left[Cff_i(s) \cdot e^{-\beta s} \cdot s^2 + Cfb_i(s)\right] \cdot X_{i-1}(s)$$

$$SS_{CACC,i}(s) = \frac{X_i(s)}{X_{i-1}(s)} = \frac{G_i(s) \cdot \left[Cff_i(s) \cdot e^{-\beta s} \cdot s^2 + Cfb_i(s)\right]}{1 + G_i(s) \cdot Cfb_i(s) \cdot H(s)}$$

- ACC

$$X_i(s) = G_i(s) \cdot Cfb_i(s) \cdot E_i(s)$$

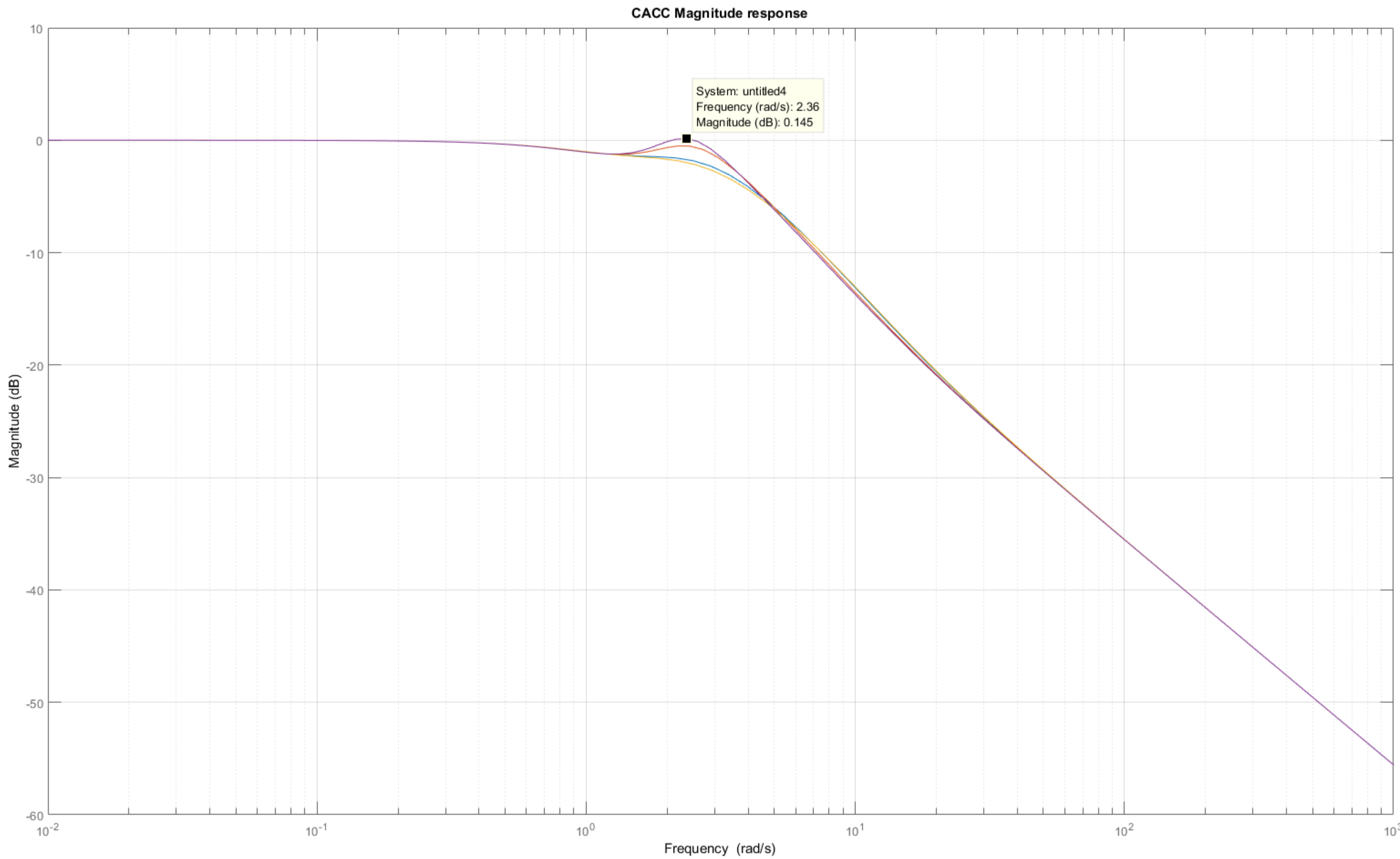
$$[1 + G_i(s) \cdot Cfb_i(s) \cdot H(s)] \cdot X_i(s)$$

$$SS_{CACC,i}(s) = \frac{X_i(s)}{X_{i-1}(s)} = \frac{G_i(s) \cdot Cfb_i(s)}{1 + G_i(s) \cdot Cfb_i(s) \cdot H(s)}$$

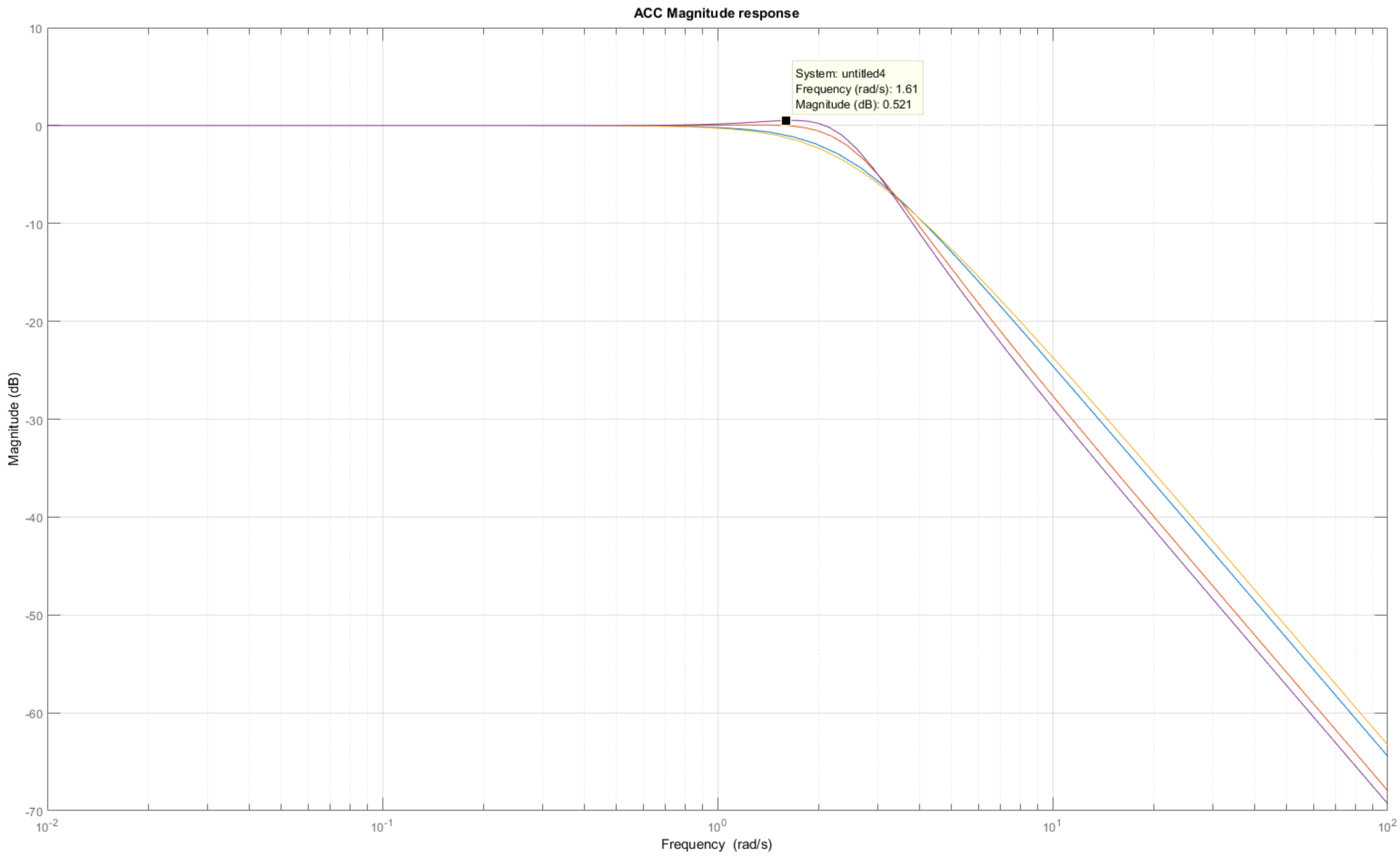
SCRIPT FOR STRING STABILITY CALCULATION


```
clear all
clc

%String Stability Analysis of Heterogeneous Convoy Vehicles

s=tf('s');

t = [0.3, 0.4, 0.6, 0.35, 0.7];
beta = 0.3;
thd = 0.6;

wk=[2.4, 2.4, 2.4, 2.4, 2.4];

e = pade(exp(-beta*s));

for k= 2:5
G = 1/(s^2*(t(k)*s+1));

H = 1 + thd*s;

Cfb = wk(k)*wk(k)  +wk(k)*s;

Cff = 1/  (s^2 *G*H);

ACC(k-1)   = Cfb*G/(1+ Cfb*G*H);

CACC(k-1)  = (Cfb + s^2*e *Cff )*G   /(1+ Cfb*G*H);

figure(1); bodemag(ACC(k-1)); hold on; grid on; title('ACC Magnitude response');
figure(2); bodemag(CACC(k-1)); hold on; grid on; title('CACC Magnitude response');
figure(3);
hold on
bodemag(ACC(k-1),'-b',CACC(k-1),'-g')
title('String stability transfer function frequency responses for ACC and CACC systems');
legend('ACC','CACC');

end
hold off
```

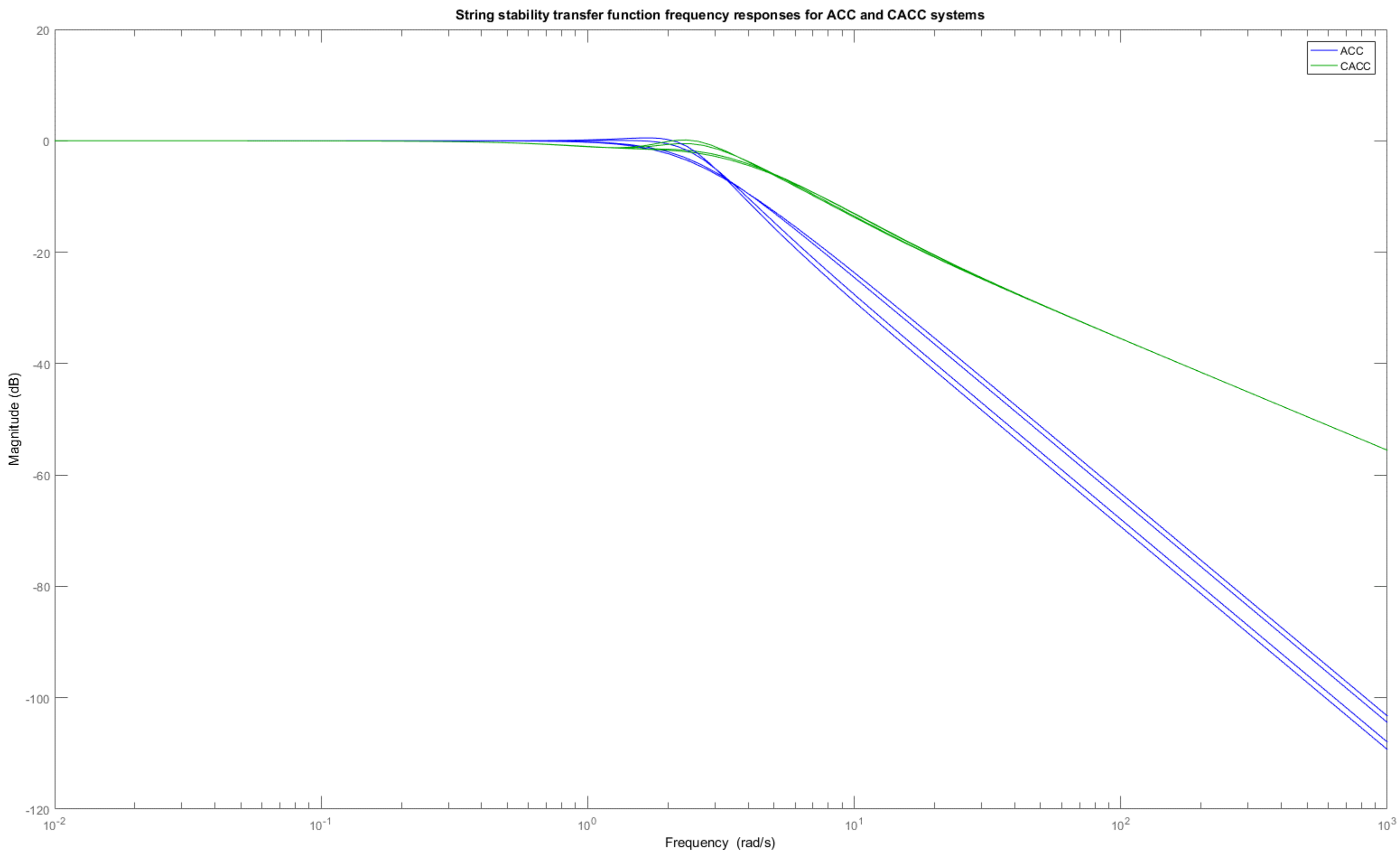
PLOTS FOR STRING STABILITY IN CACC



PLOTS FOR STRING STABILITY IN ACC



EVALUATION OF CACC SYSTEMS – STRING STABILITY



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SUBMISSION INFO

HW 3

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