Pilot Structure for 16m Uplink MIMO Collaborative Spatial Multiplexing

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Purpose:

To describe the uplink pilot structure for MIMO collaborative spatial multiplexing and to include the description in the physical layer chapter of SDD.

Pilot Structure for 16m Uplink MIMO Collaborative Spatial Multiplexing (CSM)

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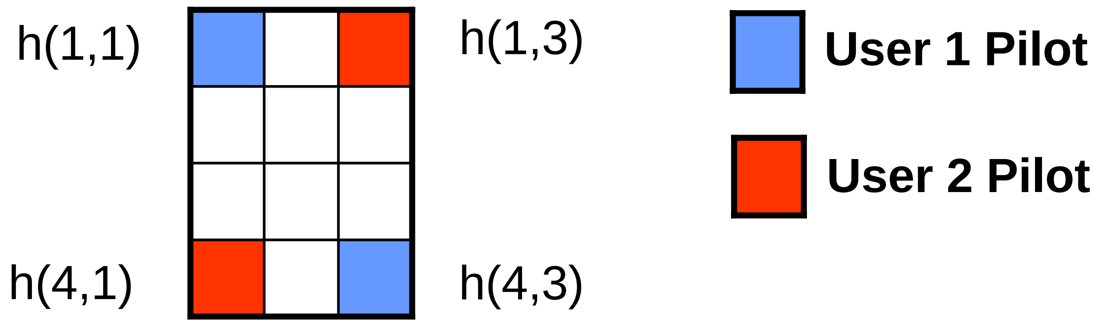
May 05, 2008

Problem Statement: 16e UL-MIMO-CSM Tile



- According to the 16e standard:
  - Timing offset is within **± 8 samples ($\Delta\tau$)**
  - Frequency offset is assumed to be **± 200 Hz** (Δf , 2% inter-carrier spacing for 10 MHz)
- Receiver must estimate and correct for timing offset and frequency offsets.
- Both timing offset and frequency offset manifest as phase ramps.
- For 16e UL-MIMO-CSM pilot structure, it is difficult to ascertain whether the phase roll was created due to timing or frequency offset since we only have the diagonal pilots.

Signal Model

- The output of the FFT at the i^{th} BTS Rx antenna and p^{th} tile, k^{th} tone and l^{th} OFDM symbol

$$y_{i,p}(k,l) = \exp\left[j\left(\theta(k,l)\right)\right] h_{i,p}(k,l)\, x_p(k,l) + u_{i,p}(k,l)$$

- Total phase ramp: $\theta(k,l) = \theta_t(k) + \theta_f(l)$
- Timing Offset (phase ramp along freq. dimension): $\theta_t(k) = -2\pi \frac{k}{N} \Delta\tau$
- Freq. Offset (phase ramp along time dimension): $\theta_f(l) = 2\pi l \varepsilon$
- W is the bandwidth, N FFT size

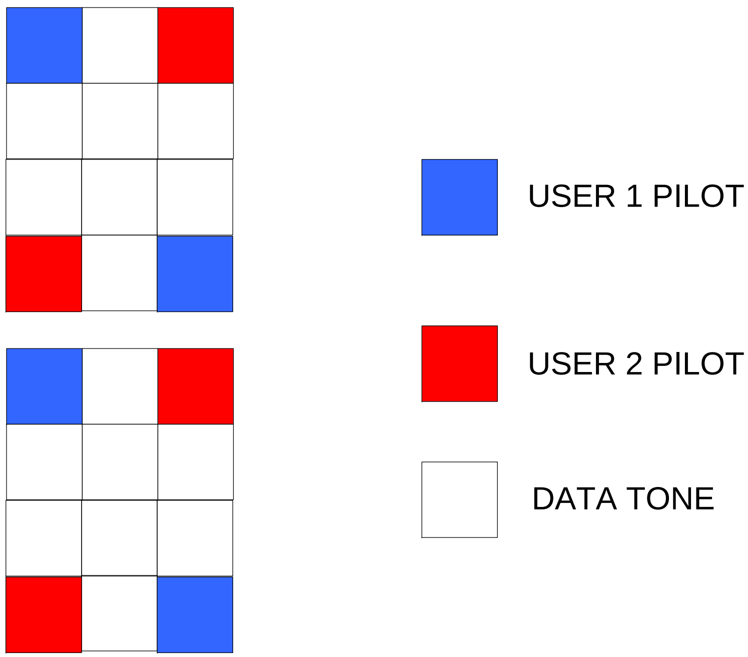
$$\varepsilon = \frac{\Delta f}{(W/N)}$$

- $x_p(k,l)$ is the pilot symbol p^{th} tile, k^{th} tone and l^{th} OFDM
- $h_{i,p}(k,l)$ is the frequency response of the channel i^{th} BTS Rx antenna and p^{th} tile, k^{th} tone and l^{th} OFDM symbol

Uplink Tile/Pilot Structure

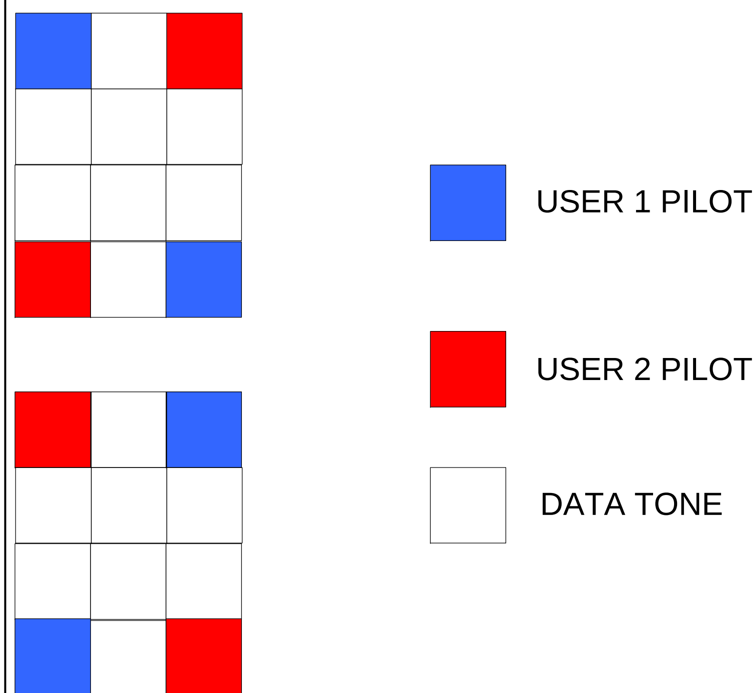
16e UL-MIMO CSM Tile

- Pilots of Users 1 and 2 are in fixed positions along tiles of a sub-channel



16m UL-MIMO CSM Tile

- Pilots of Users 1 and 2 are rotated along the tiles of a sub-channel



Exploiting the New Pilot Structure (1)

- The rotating pilot structure along tiles of a sub-channel are used to separate the phase contribution due timing offset (θ_t) from the phase contribution due to frequency offset (θ_f) by creating two independent equations with the two unknowns
- Examine the following two equations generated by two vertical tiles in the same sub-channel (tiles *p* and *p*+1) for a given antenna

$$z_p = \left[\frac{y_{i,p}(k,l)}{x_p(k,l)}\right]^* \left[\frac{y_{i,p}(k+3,l+2)}{x_p(k+3,l+2)}\right] \quad , \quad \measuredangle z_p = 2\theta_f + 3\theta_t$$

$$z_{p+1} = \left[\frac{y_{i,p+1}(k+3,l)}{x_{p+1}(k+3,l)}\right]^* \left[\frac{y(k,l+2)}{x_{p+1}(k,l+2)}\right] \quad , \quad \measuredangle z_{p+1} = 2\theta_f - 3\theta_t$$

Exploiting the New Pilot Structure (2)

- It is easy to solve now for the two unknowns (phase contribution due timing offset and phase contribution due to frequency offset) from the two independent equations, or
- An alternative is to

$$\theta_t = \frac{1}{4} \measuredangle \left(z_p z_{p+1} \right)$$

$$\theta_f = \frac{1}{6} \measuredangle \left(z_p z_{p+1}^{*} \right)$$

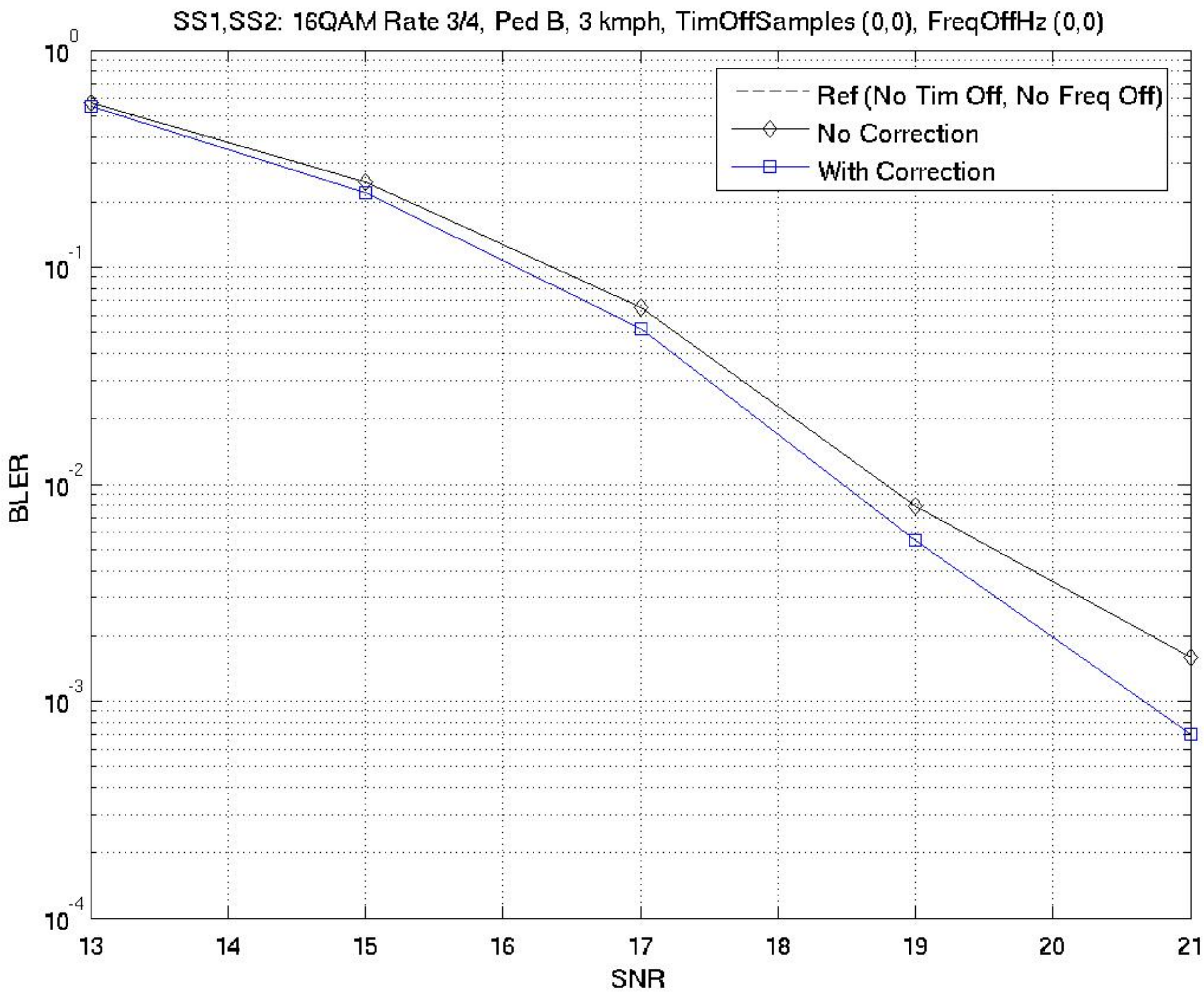
- The estimates of the phase contribution due timing offset and phase contribution due to frequency offset shown in this example are from a pair of tiles and a single antenna. These estimates can be improved using multiple tiles and multiple antennas
  - Tiles in sub-channels are used to improve the estimates
  - Antennas at the receiver can also be used to improve the estimates

Simulation Scenario I

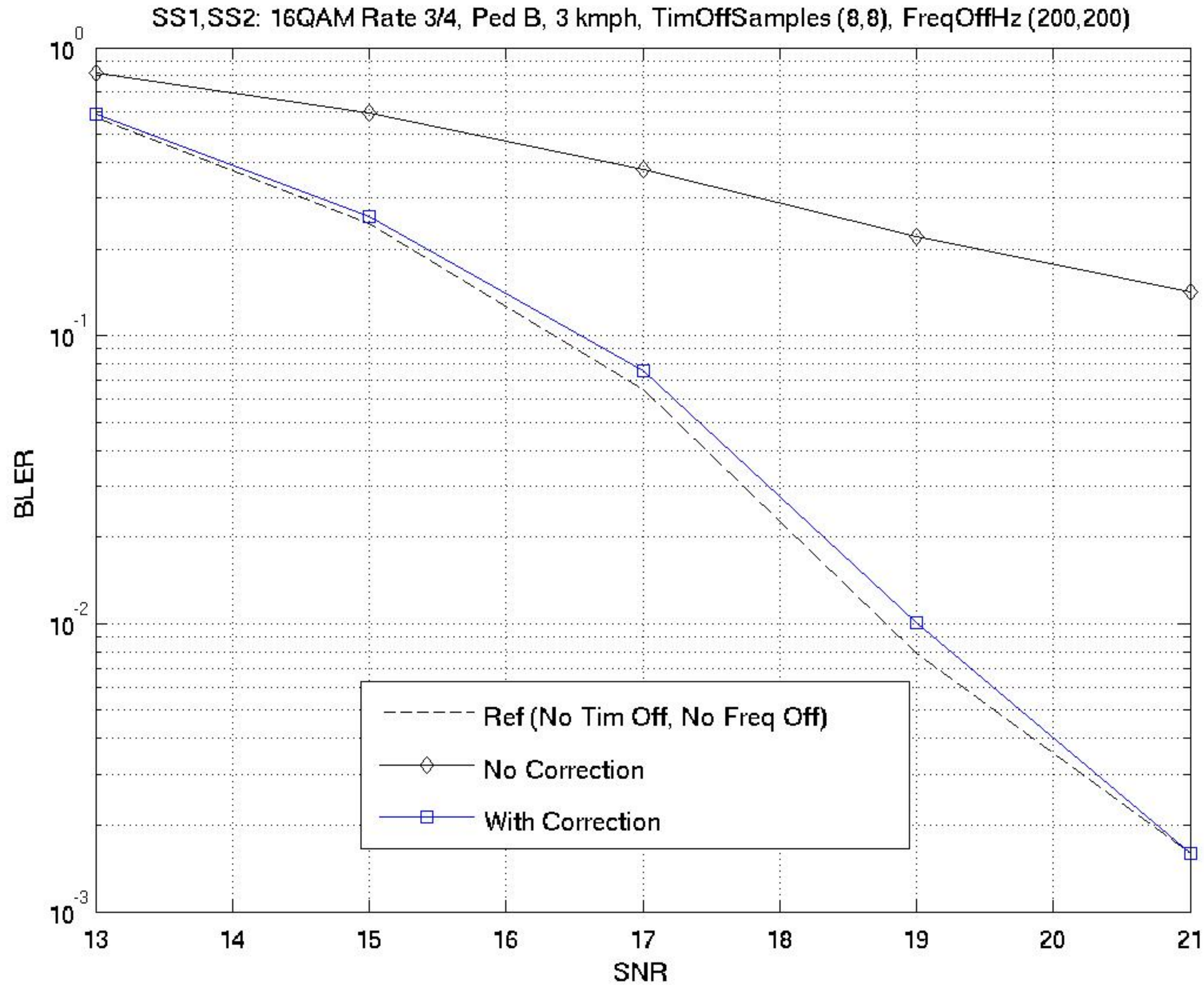
- SS#1, SS#2: 16QAM Rate ¾, Ped B, 3 kmph.

Tim. Off. SS#1 (Samples)	Tim. Off. SS#2 (Samples)	Freq. Off. SS#1 (Hz)	Freq. Off. SS#2 (Hz)
0	0	0	0
8	8	200	200
8	-8	200	200
-8	-8	200	200
8	8	200	-200
8	8	-200	-200

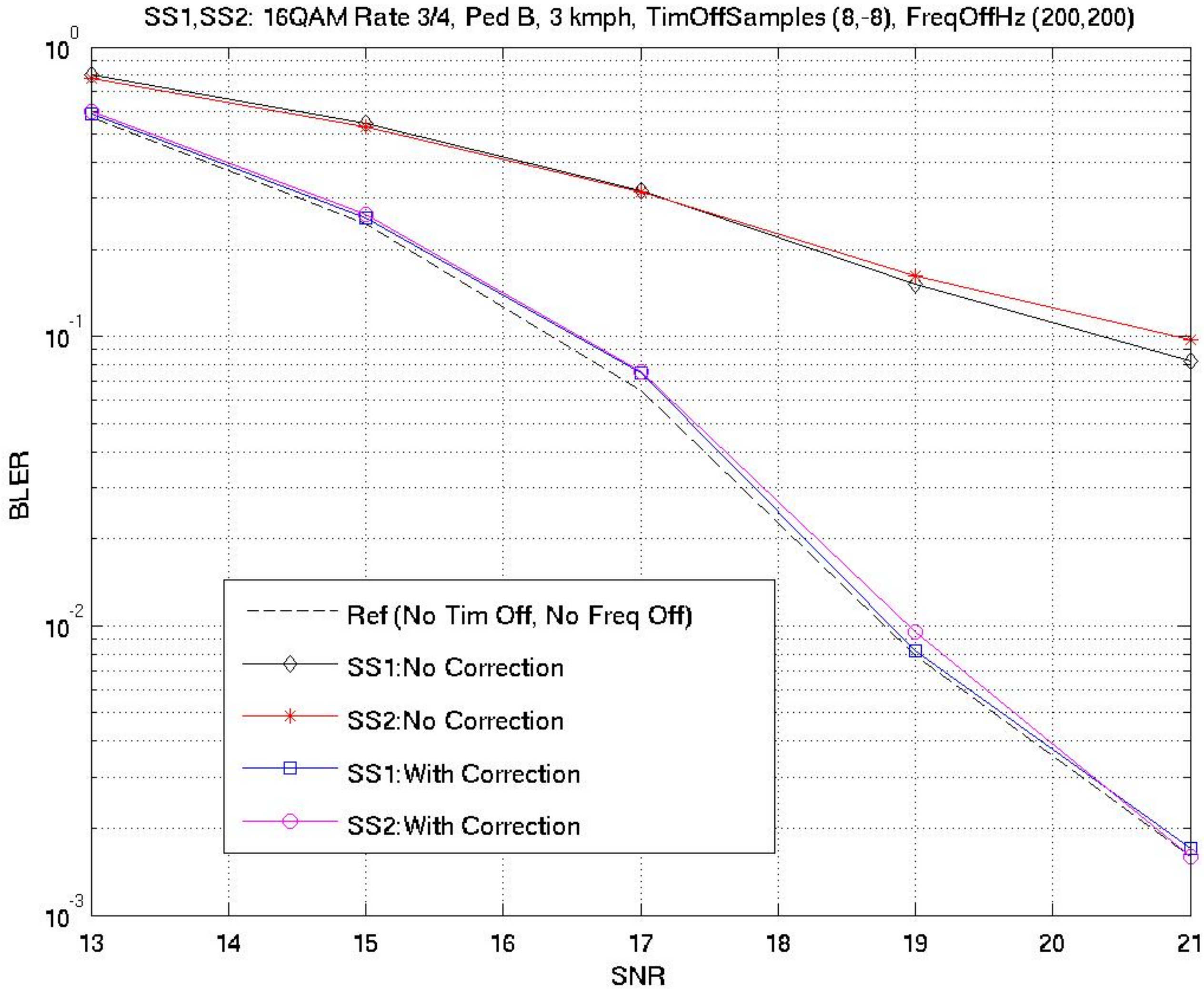
SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph
Tim Off. (Samples): (0,0), Freq Off. (Hz): (0,0)



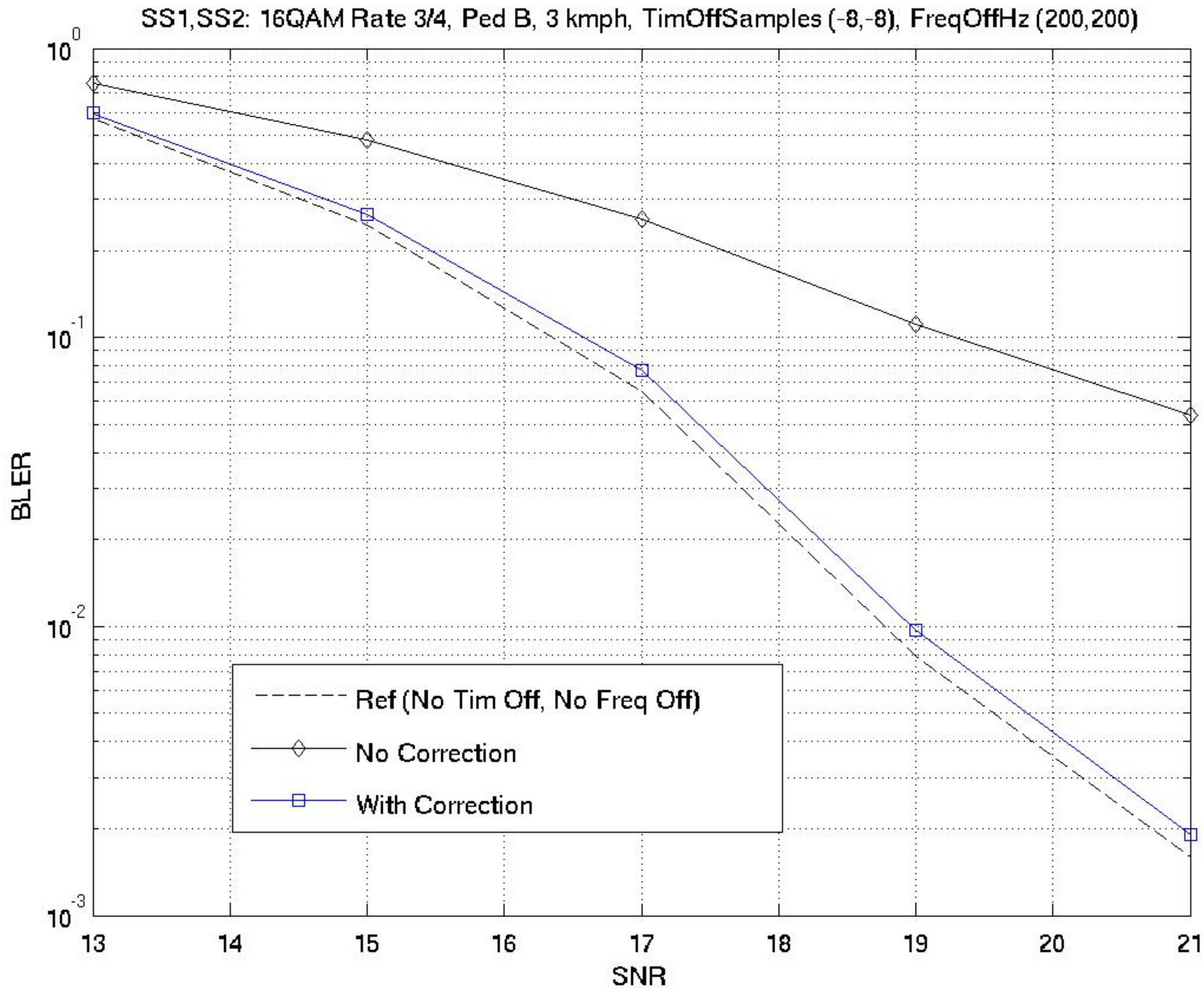
SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph
Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,200)



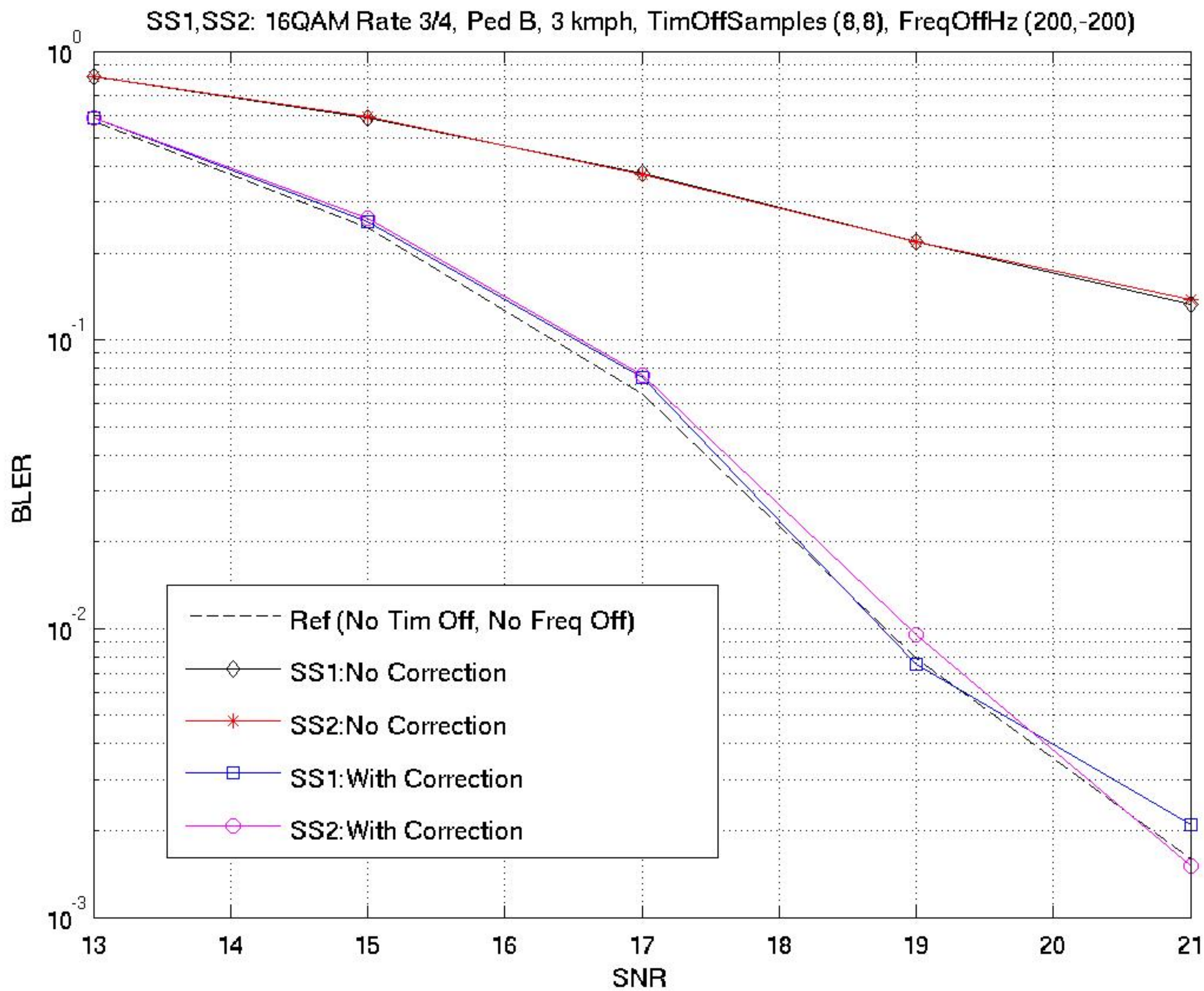
SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph
Tim Off. (Samples): (8,-8), Freq Off. (Hz): (200,200)



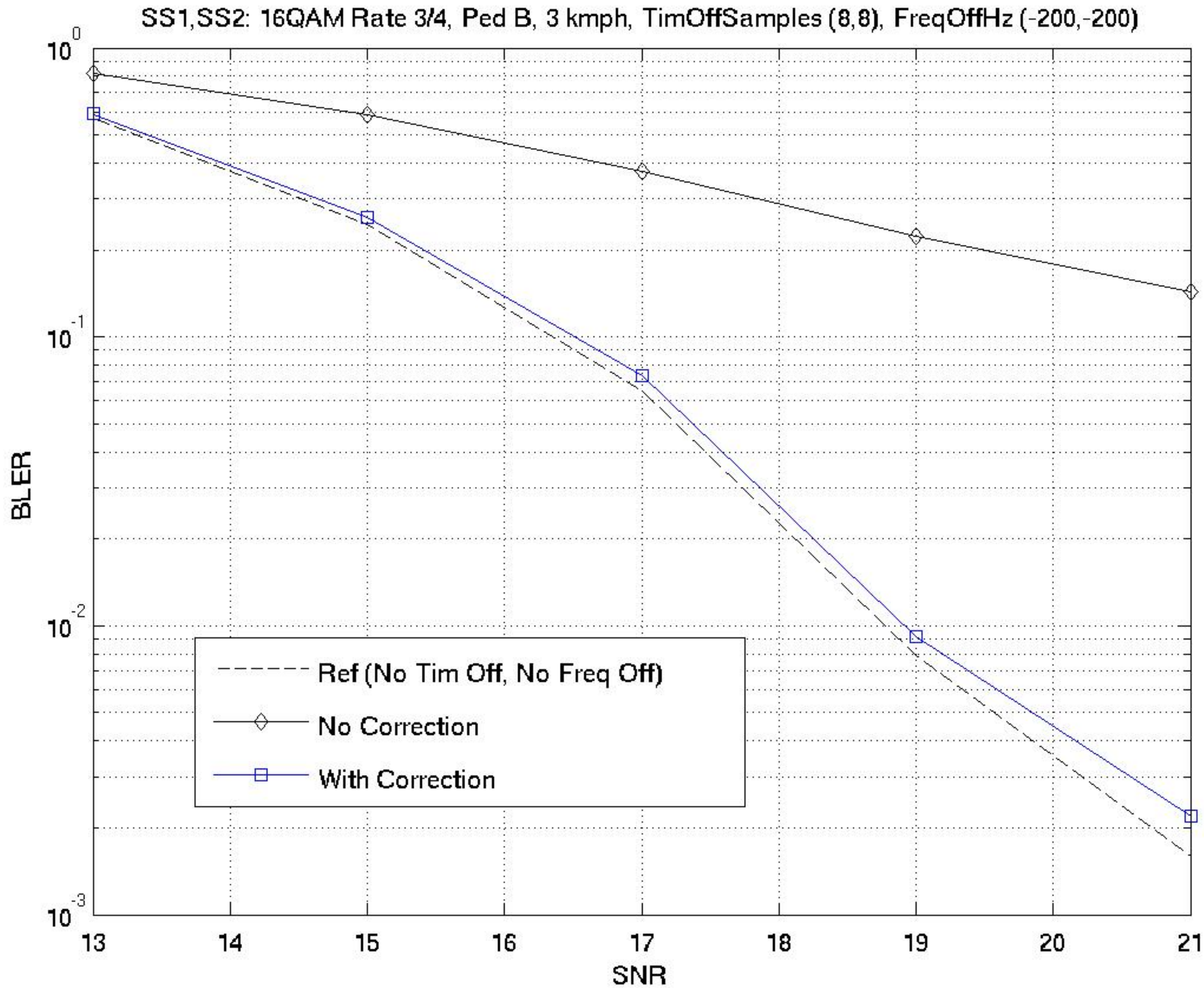
SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph
Tim Off. (Samples): (-8,-8), Freq Off. (Hz): (200,200)



SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph
Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,-200)



SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph
Tim Off. (Samples): (8,8), Freq Off. (Hz): (-200,-200)

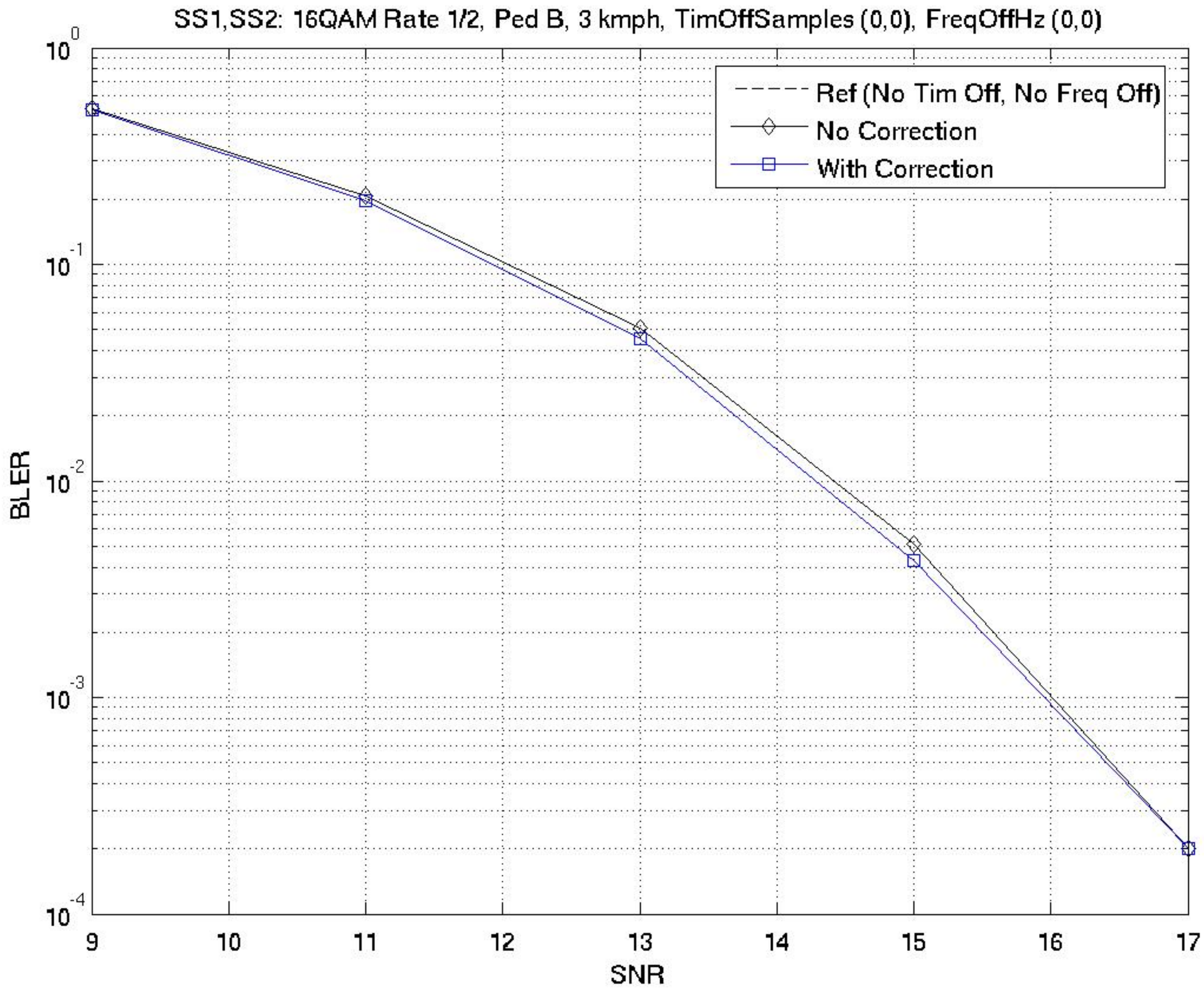


Simulation Scenario II

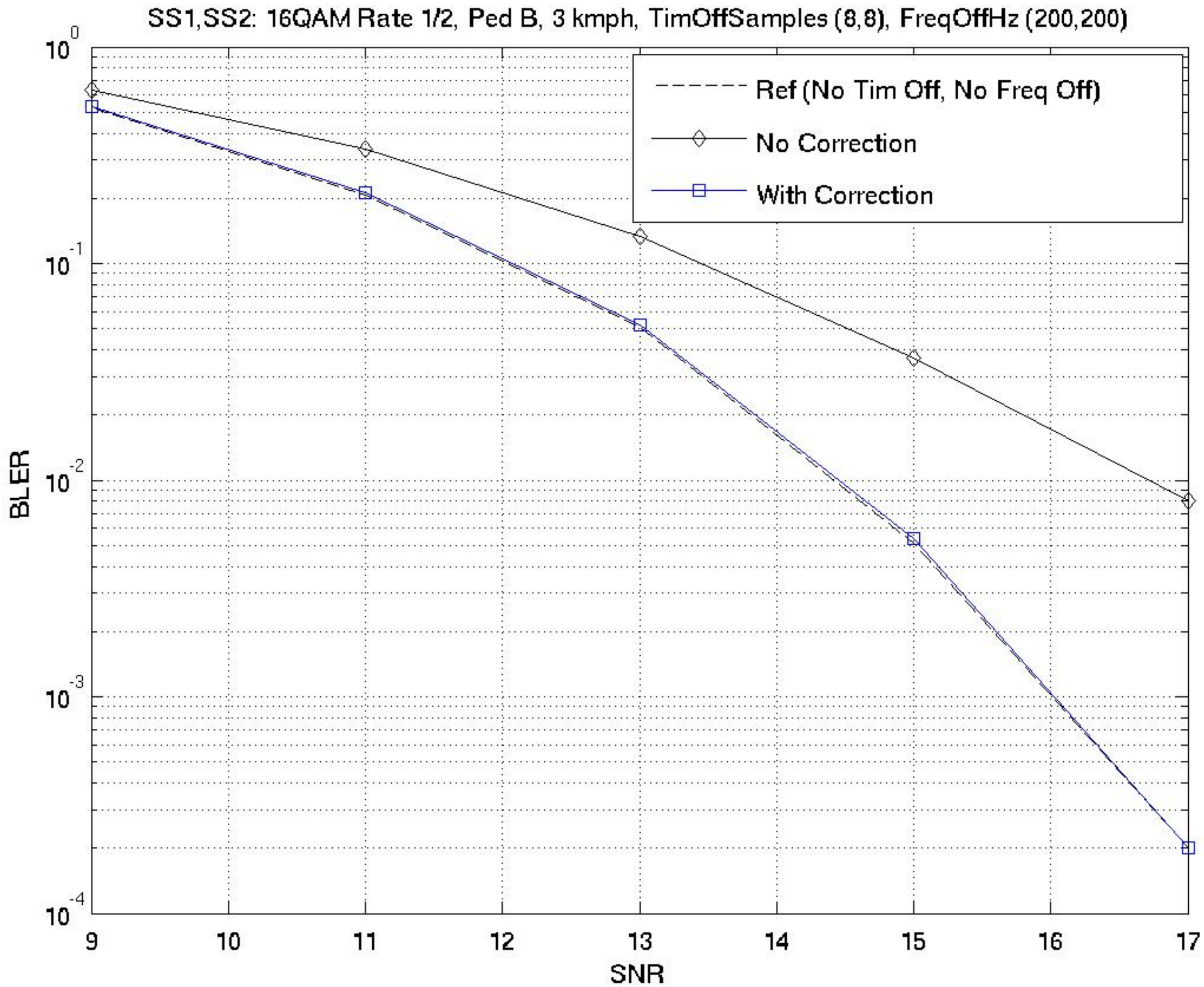
- SS#1, SS#2: 16QAM Rate ½, Ped B, 3 kmph.

Tim. Off. SS#1 (Samples)	Tim. Off. SS#2 (Samples)	Freq. Off. SS#1 (Hz)	Freq. Off. SS#2 (Hz)
0	0	0	0
8	8	200	200
8	-8	200	200
-8	-8	200	200
8	8	200	-200
8	8	-200	-200

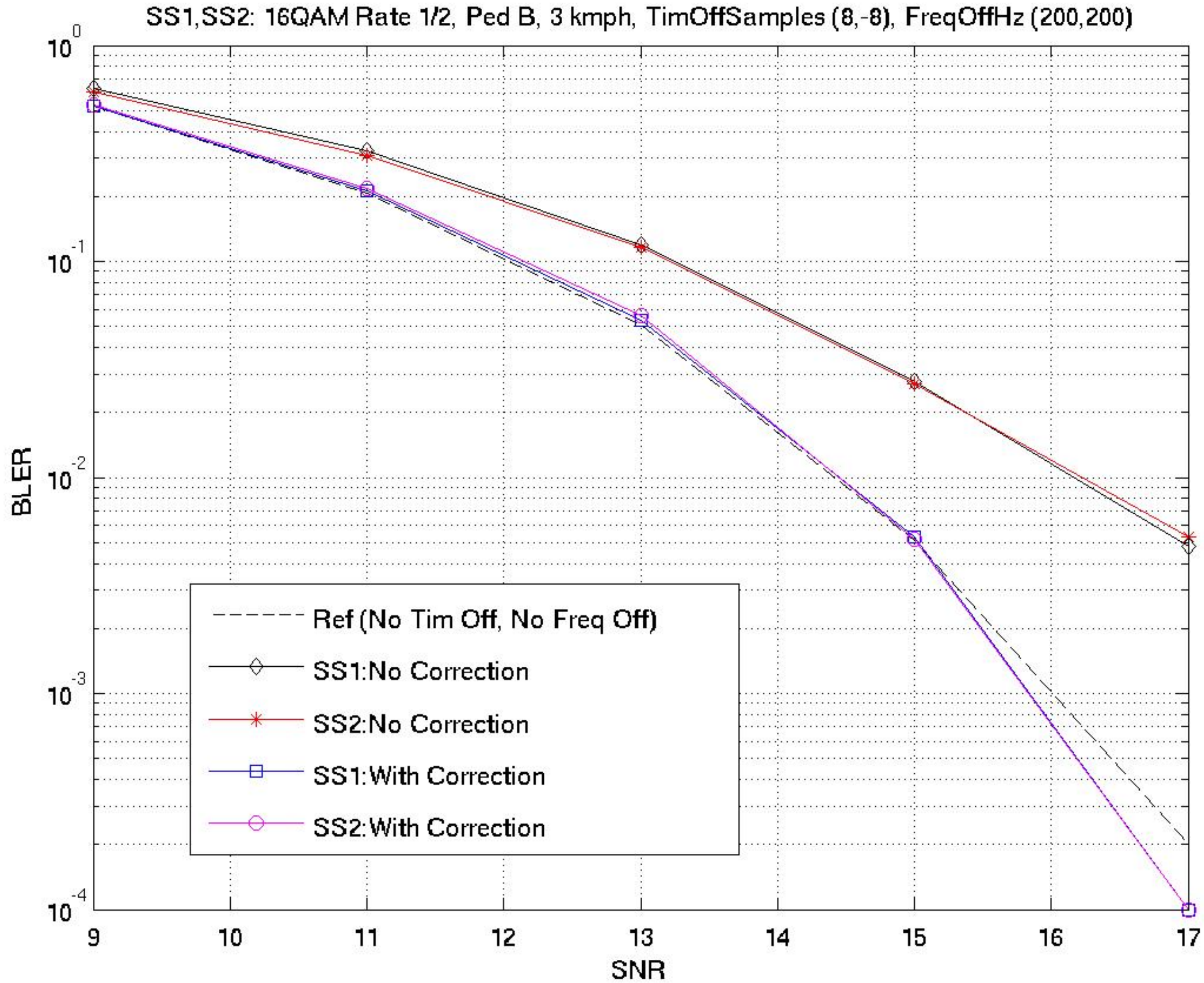
SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph
Tim Off. (Samples): (0,0), Freq Off. (Hz): (0,0)



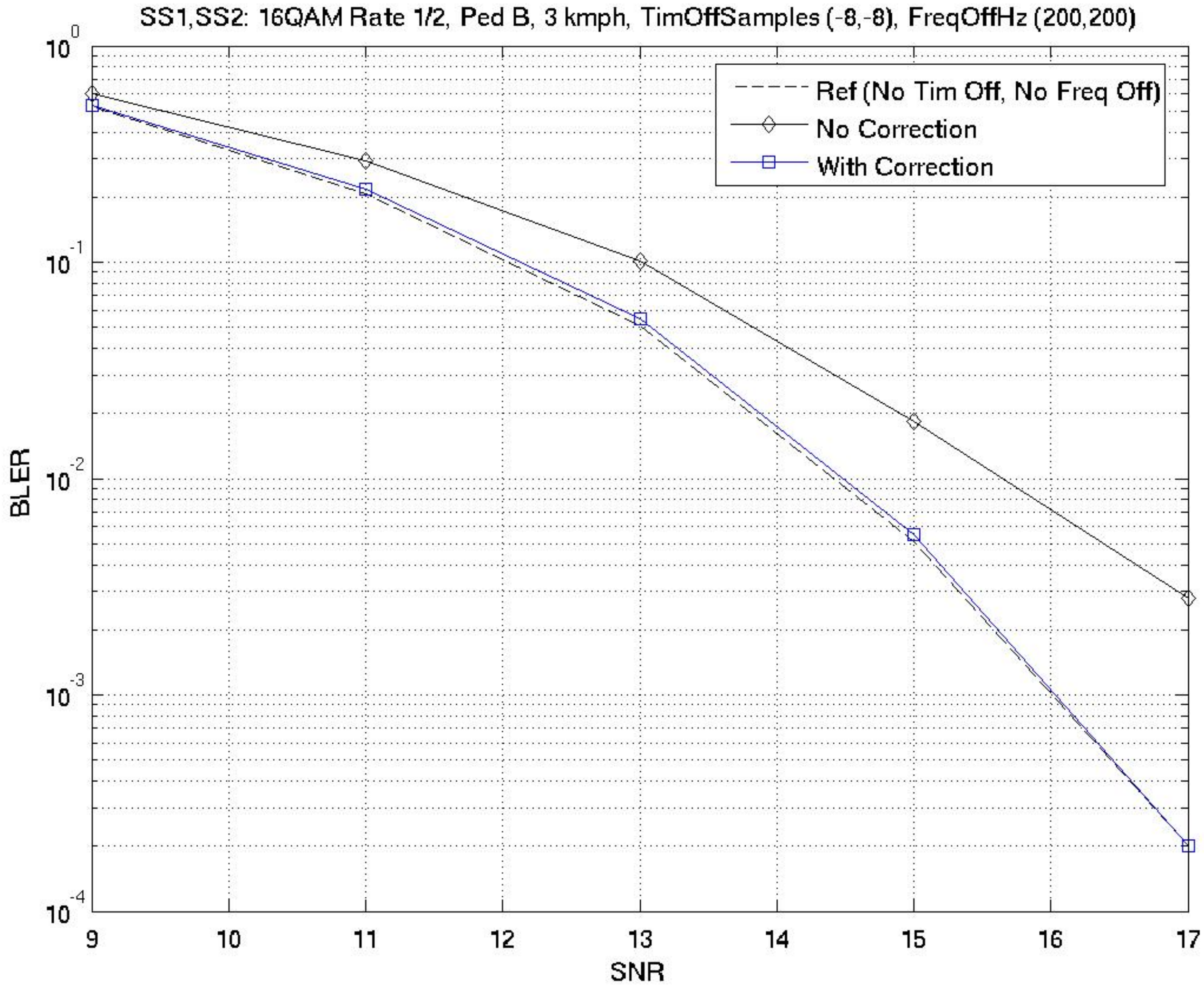
SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph
Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,200)



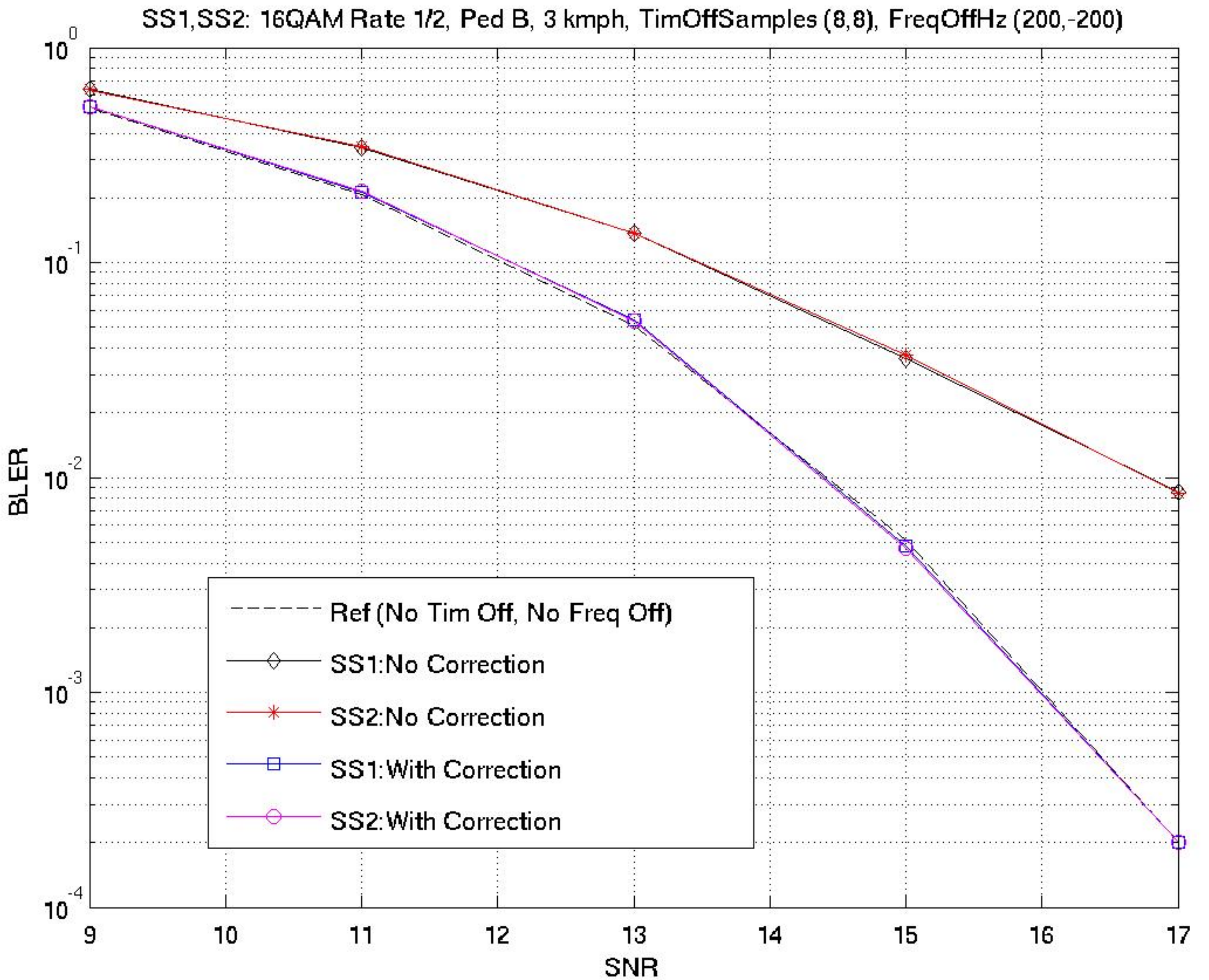
SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph
Tim Off. (Samples): (8,-8), Freq Off. (Hz): (200,200)



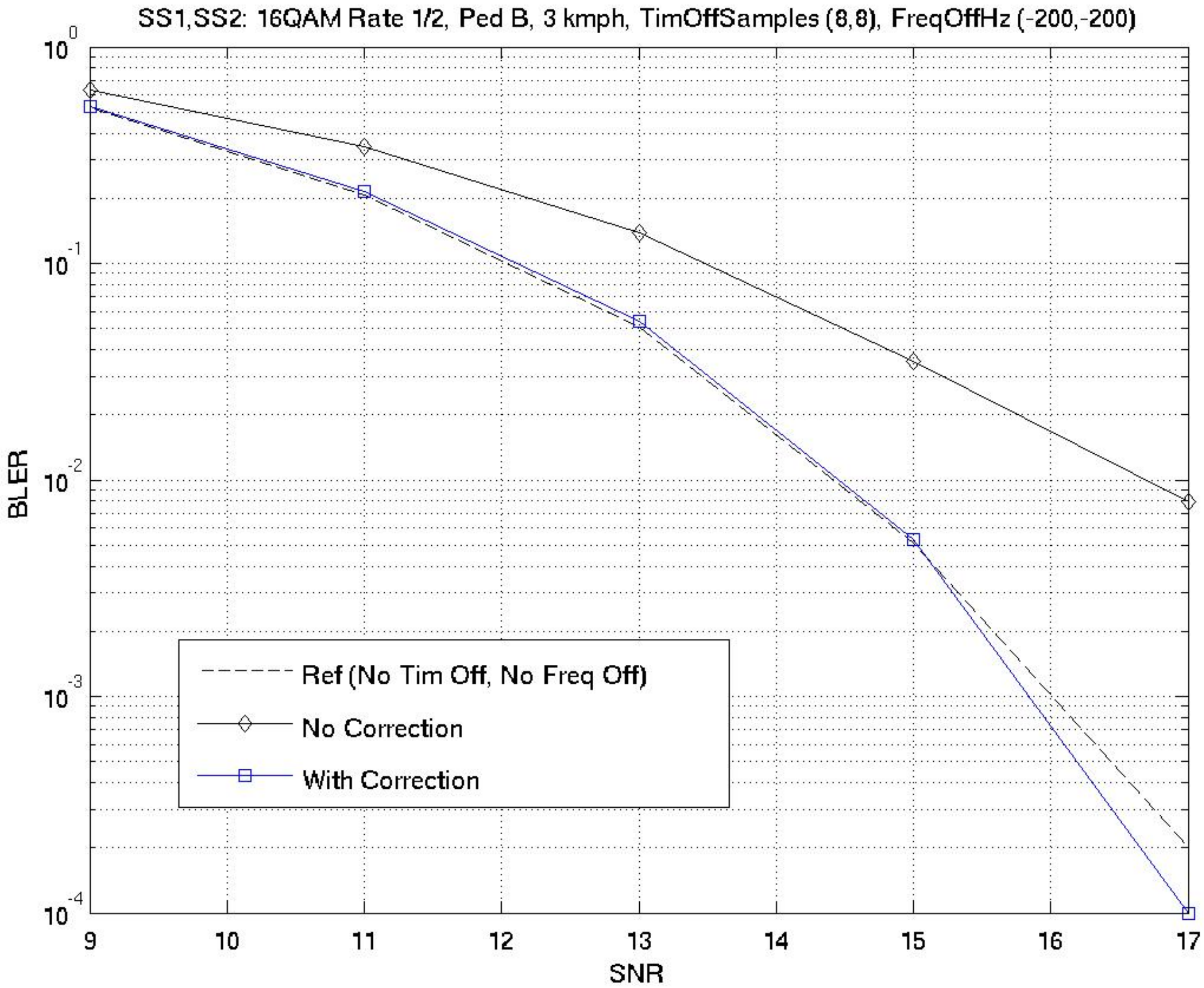
SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph
Tim Off. (Samples): (-8,-8), Freq Off. (Hz): (200,200)



SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph
Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,-200)



SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph
Tim Off. (Samples): (8,8), Freq Off. (Hz): (-200,-200)

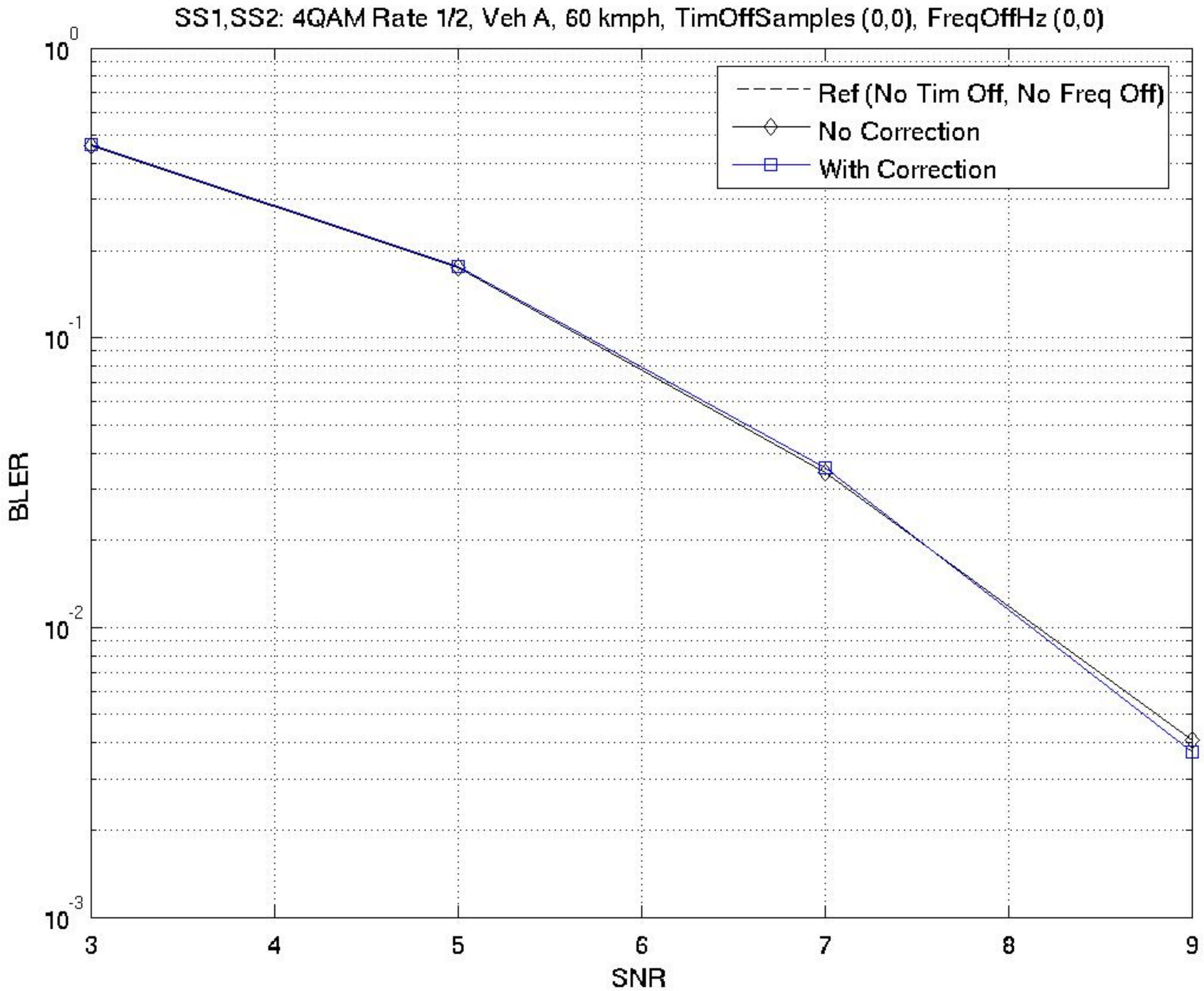


Simulation Scenario III

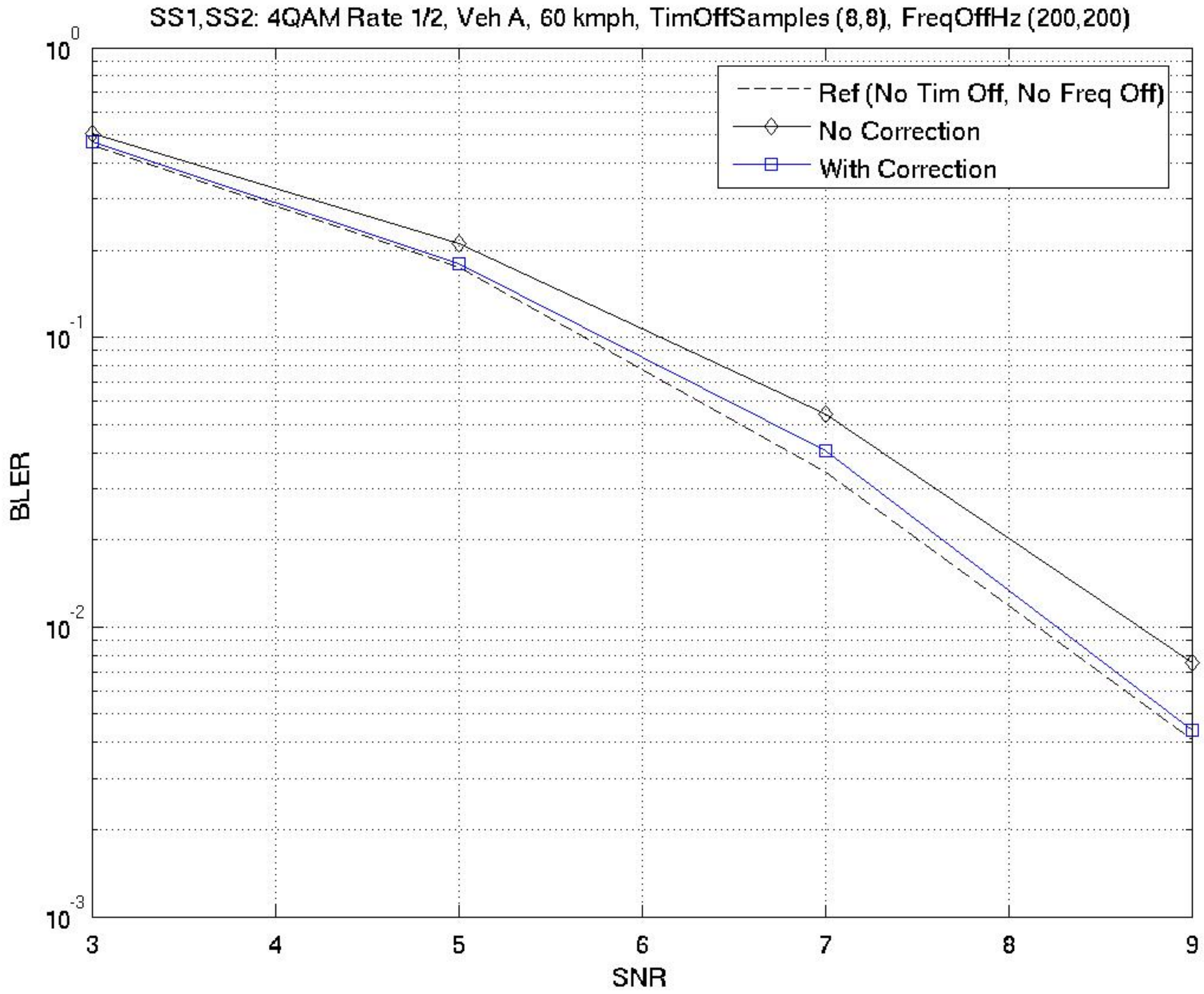
- SS#1, SS#2: 4QAM Rate ½, Veh A, 60 kmph.

Tim. Off. SS#1 (Samples)	Tim. Off. SS#2 (Samples)	Freq. Off. SS#1 (Hz)	Freq. Off. SS#2 (Hz)
0	0	0	0
8	8	200	200
8	-8	200	200
-8	-8	200	200
8	8	200	-200
8	8	-200	-200

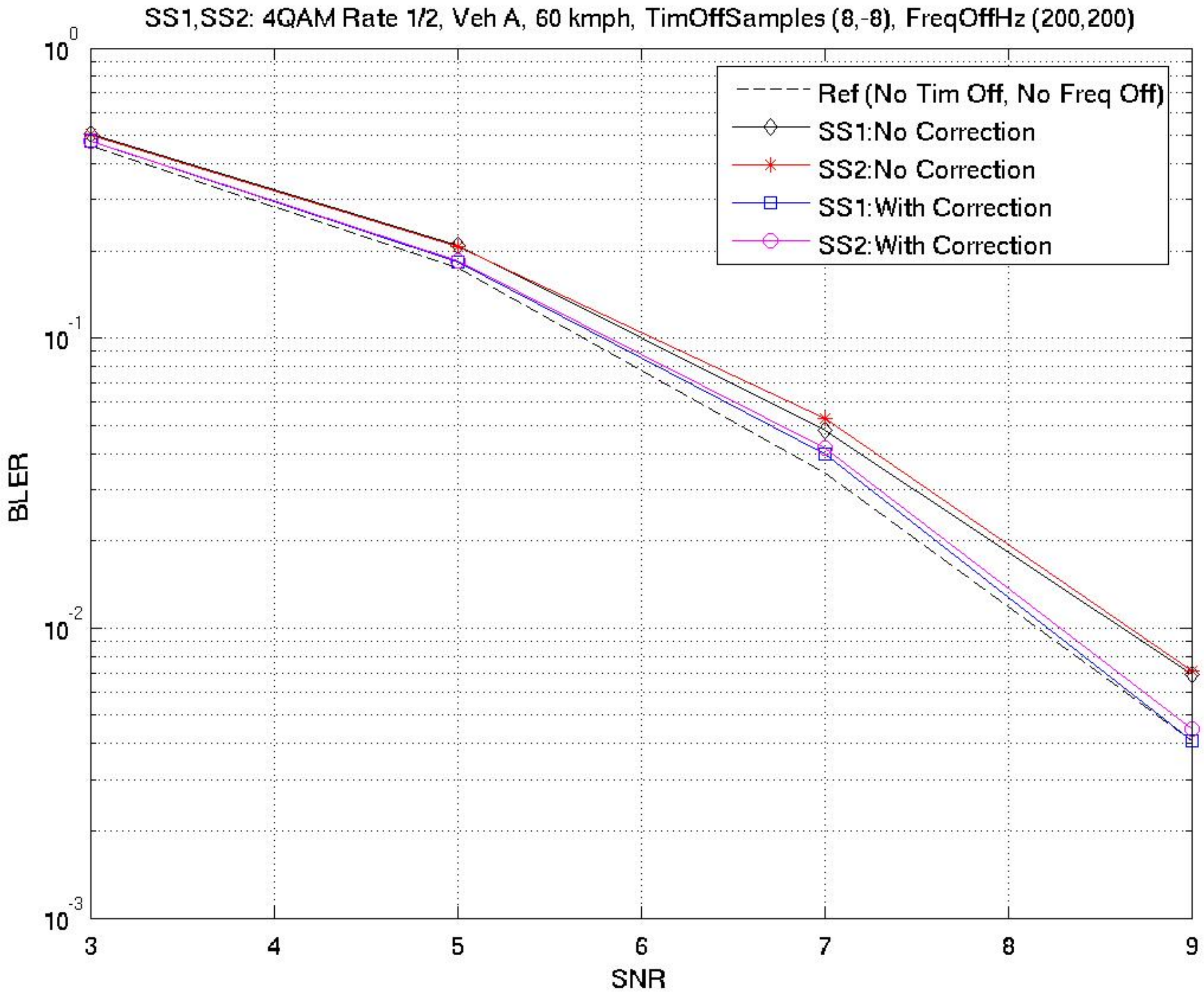
SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph
Tim Off. (Samples): (0,0), Freq Off. (Hz): (0,0)



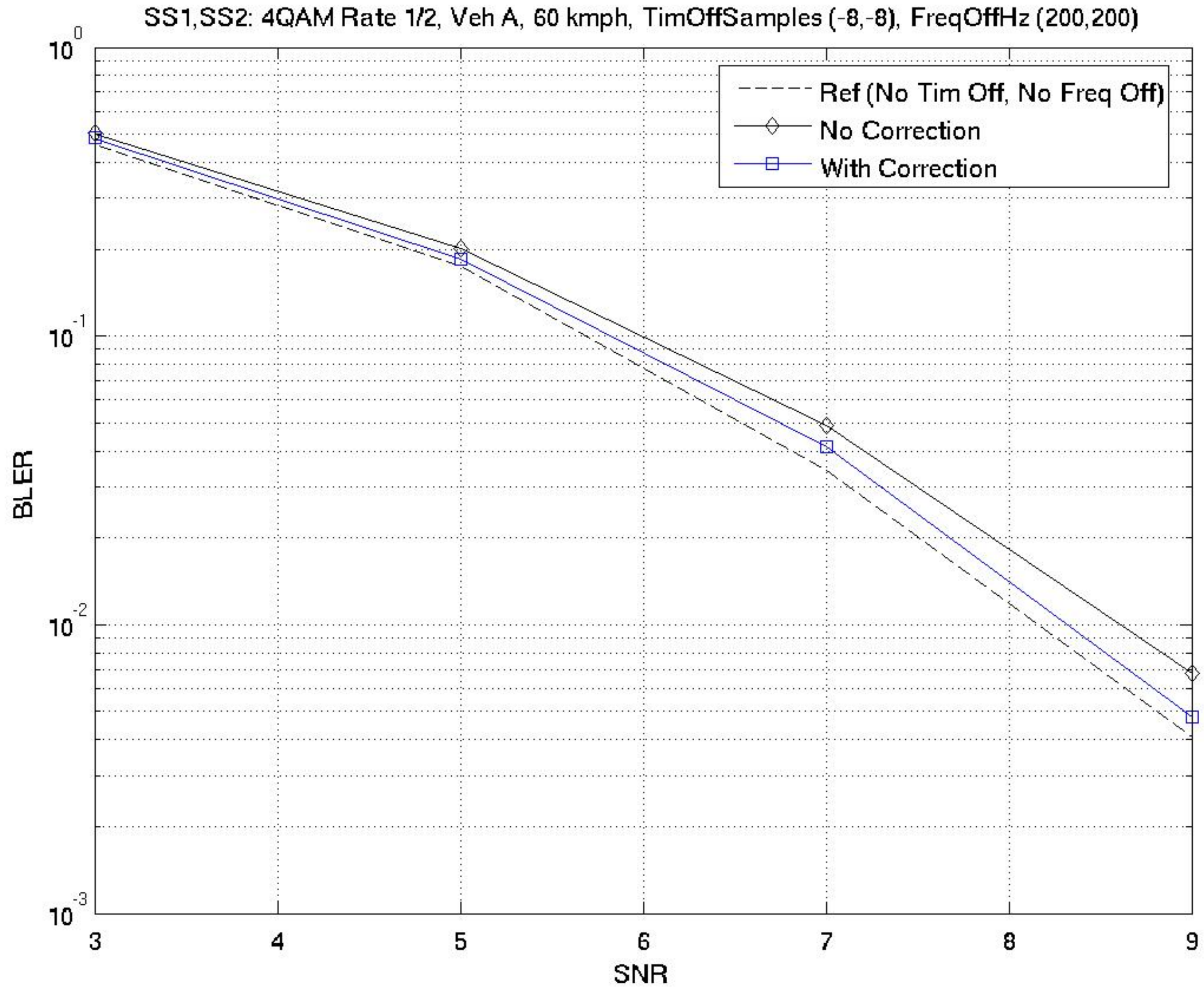
SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph
Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,200)



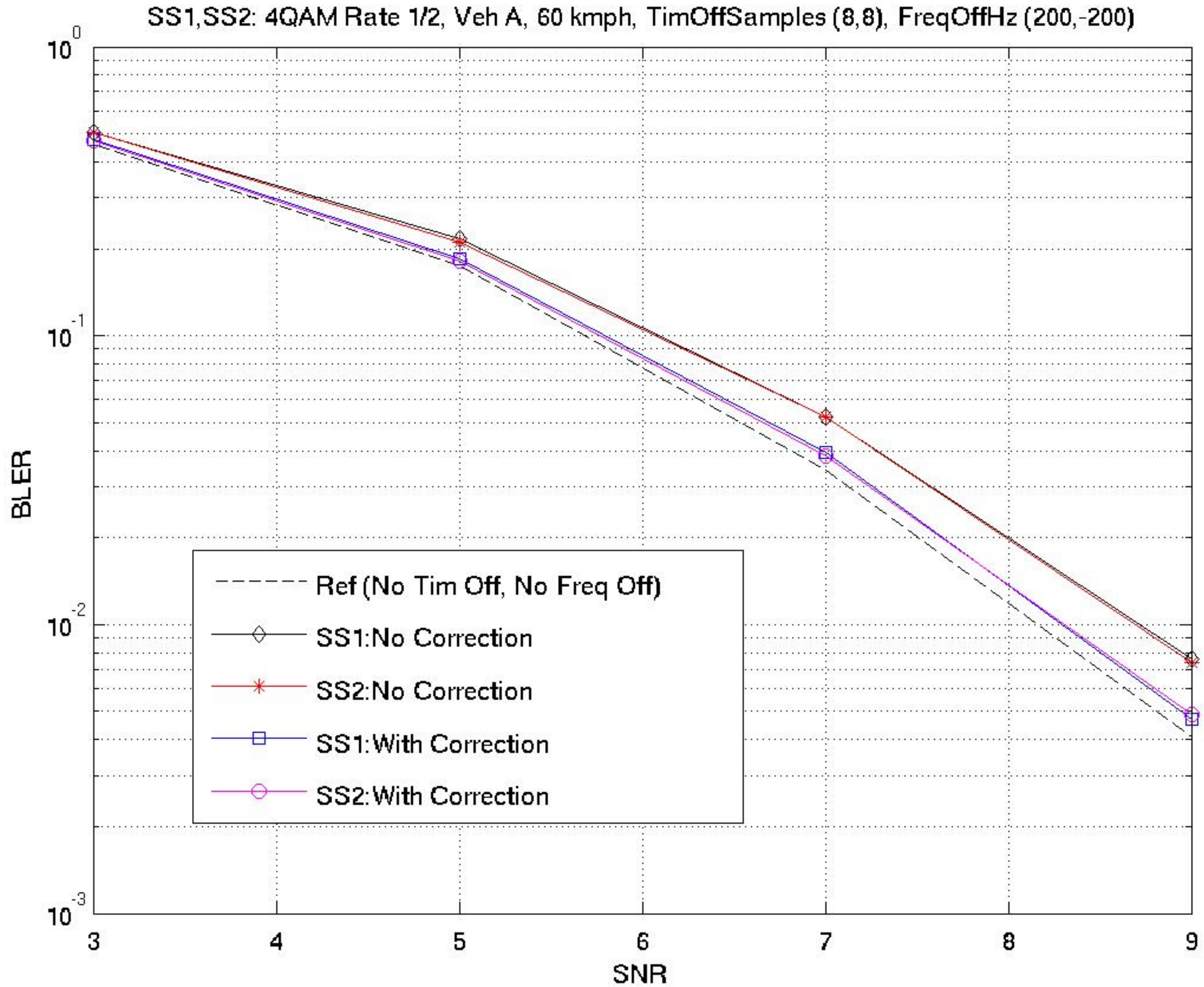
SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph
Tim Off. (Samples): (8,-8), Freq Off. (Hz): (200,200)



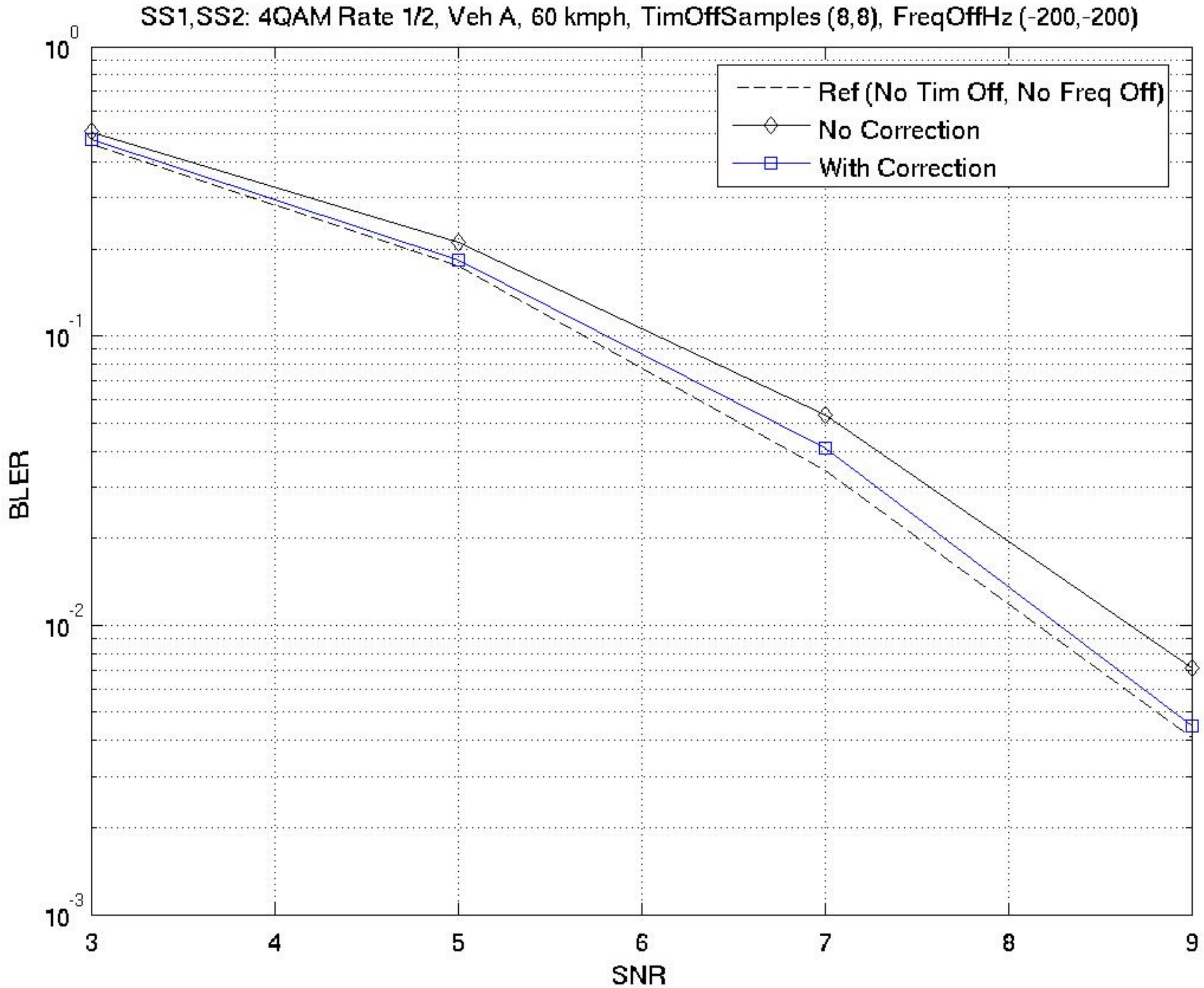
SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph
Tim Off. (Samples): (-8,-8), Freq Off. (Hz): (200,200)



SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph
Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,-200)



SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph
Tim Off. (Samples): (8,8), Freq Off. (Hz): (-200,-200)



Text for the SDD

- The *s*-th (*s* = 0,1) subscriber in the uplink MIMO CSM pair shall use tile structure *t* (*t* = 0,1) on the *k*-th tile, where *t* = mod(*s*+*k*,2)