Pilot Structure for 16m Uplink MIMO Collaborative Spatial Multiplexing

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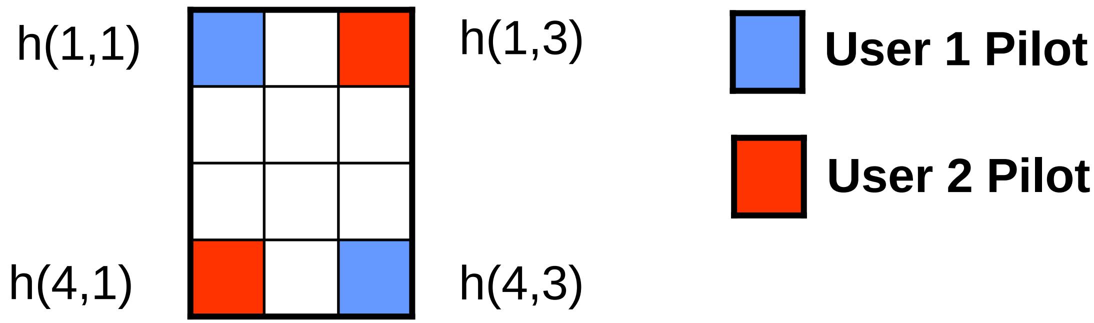
Purpose:
To describe the uplink pilot structure for MIMO collaborative spatial multiplexing and to include in Uplink Pilot Structure of System Description Document SDD.

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 *ith* BTS Rx antenna and *pth* tile, *kth* tone and *lth* OFDM symbol

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

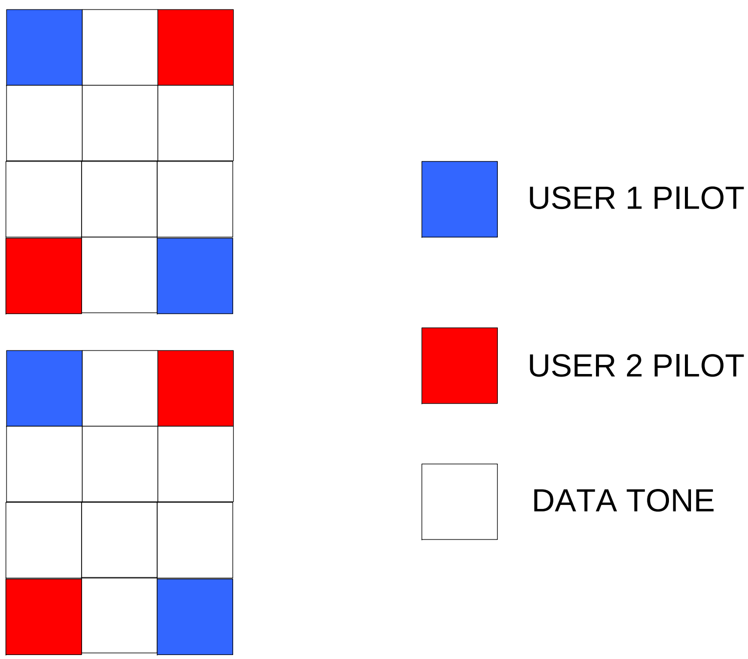
- Total phase ramp: $\theta(k,l) = \theta_t(k) + \theta_f(l)$
- Timing Offset (phase ramp along freq. dimension): $\theta_t(k) = -2\pi \frac{k}{N} \Delta\tau$
- Freq. Offset (phase ramp along time dimension): $\theta_f(l) = 2\pi l \varepsilon$
- *W* is the bandwidth, *N* FFT size

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

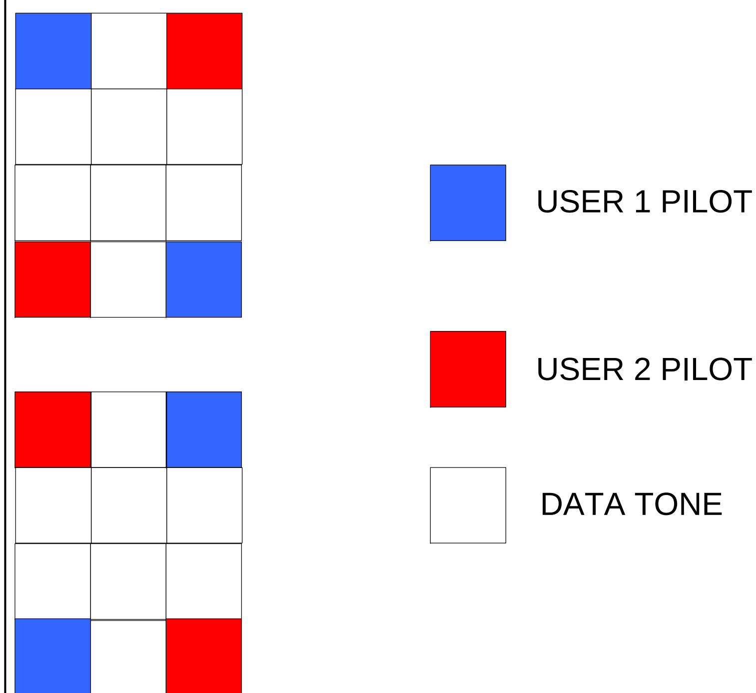
- $x_p(k,l)$ is the pilot symbol p^{th} tile, k^{th} tone and l^{th} OFDM
- $h_{i,p}(k,l)$ is the frequency response of the channel i^{th} BTS Rx antenna and p^{th} tile, k^{th} tone and l^{th} OFDM symbol

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

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

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

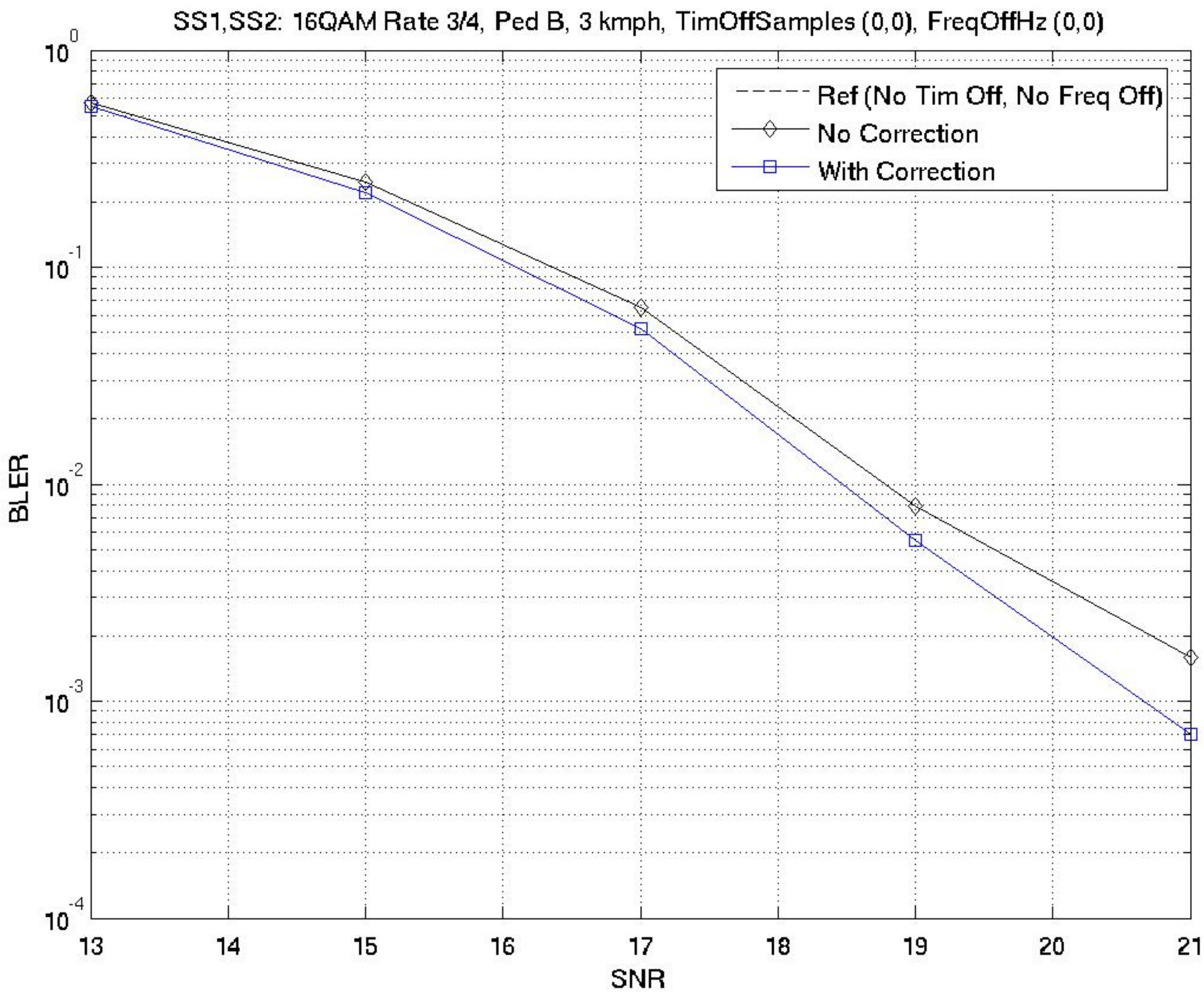
- The estimates of the phase contribution due timing offset and phase contribution due to frequency offset shown in this example are from a pair of tiles and a single antenna. These estimates can be improved using multiple tiles and multiple antennas
  - Tiles in sub-channels are used to improve the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

Simulation Scenario I

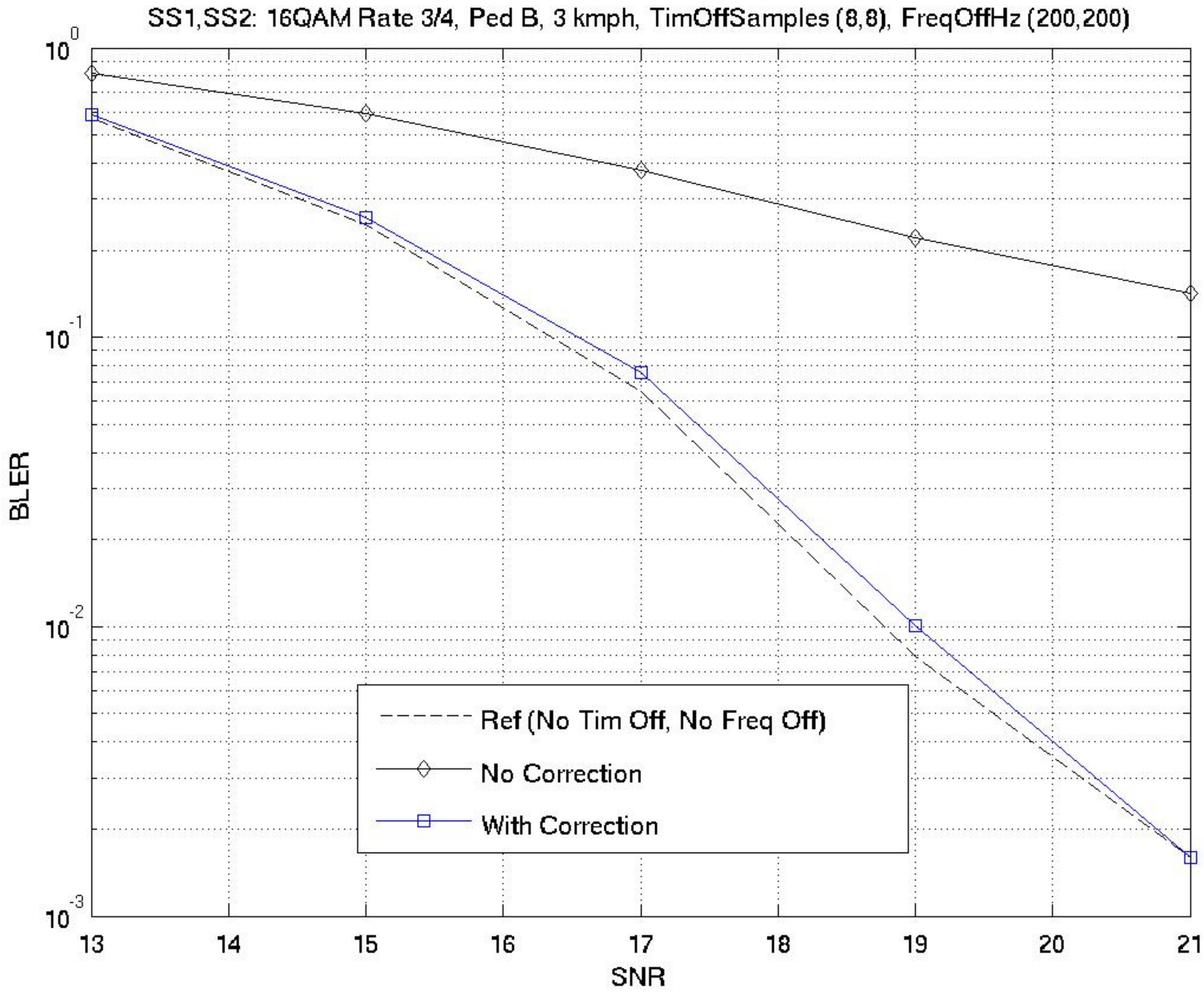
- SS#1, SS#2: 16QAM Rate ¾, Ped B, 3 kmph.

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

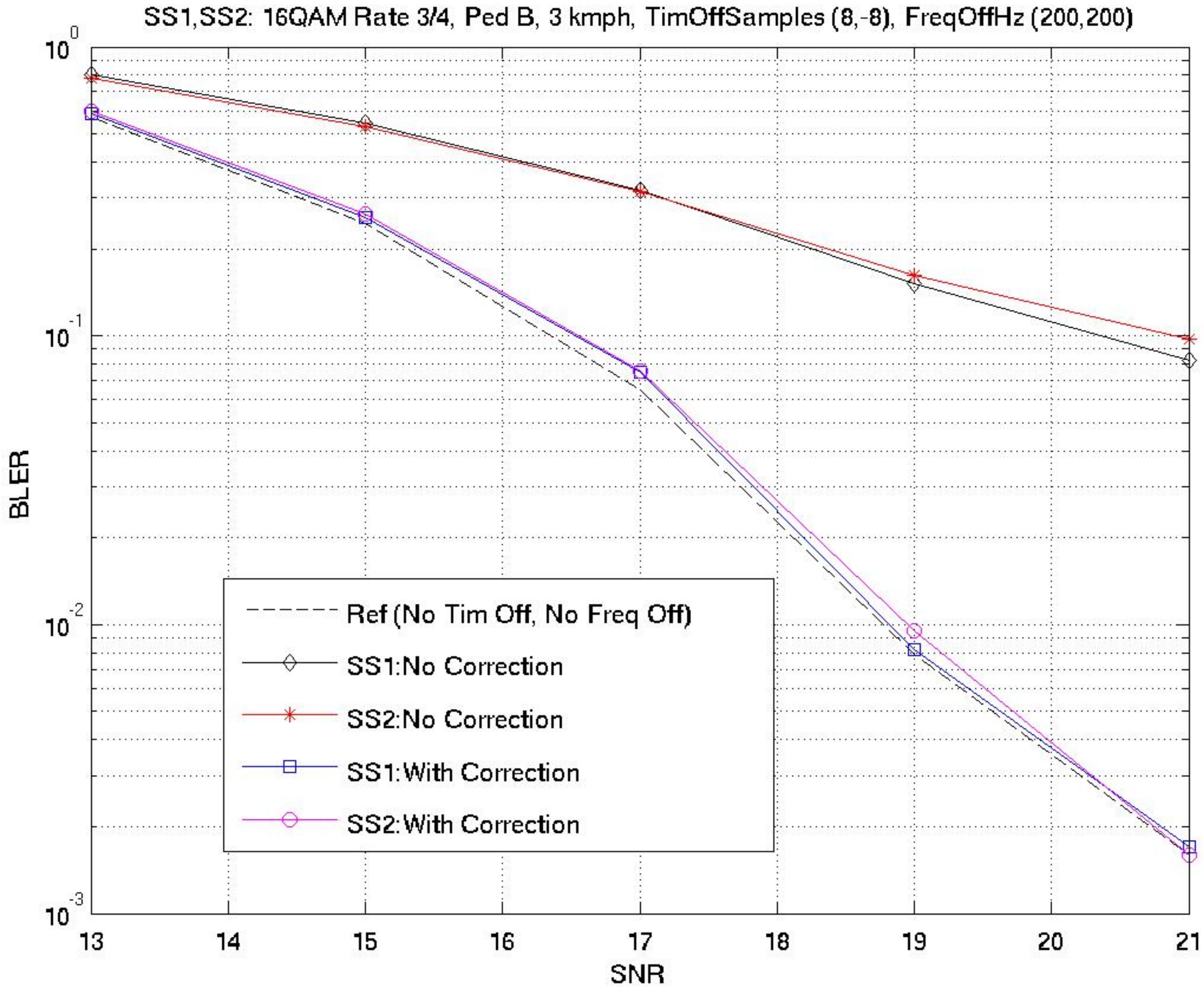
SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph
Tim Off. (Samples): (0,0), Freq Off. (Hz): (0,0)



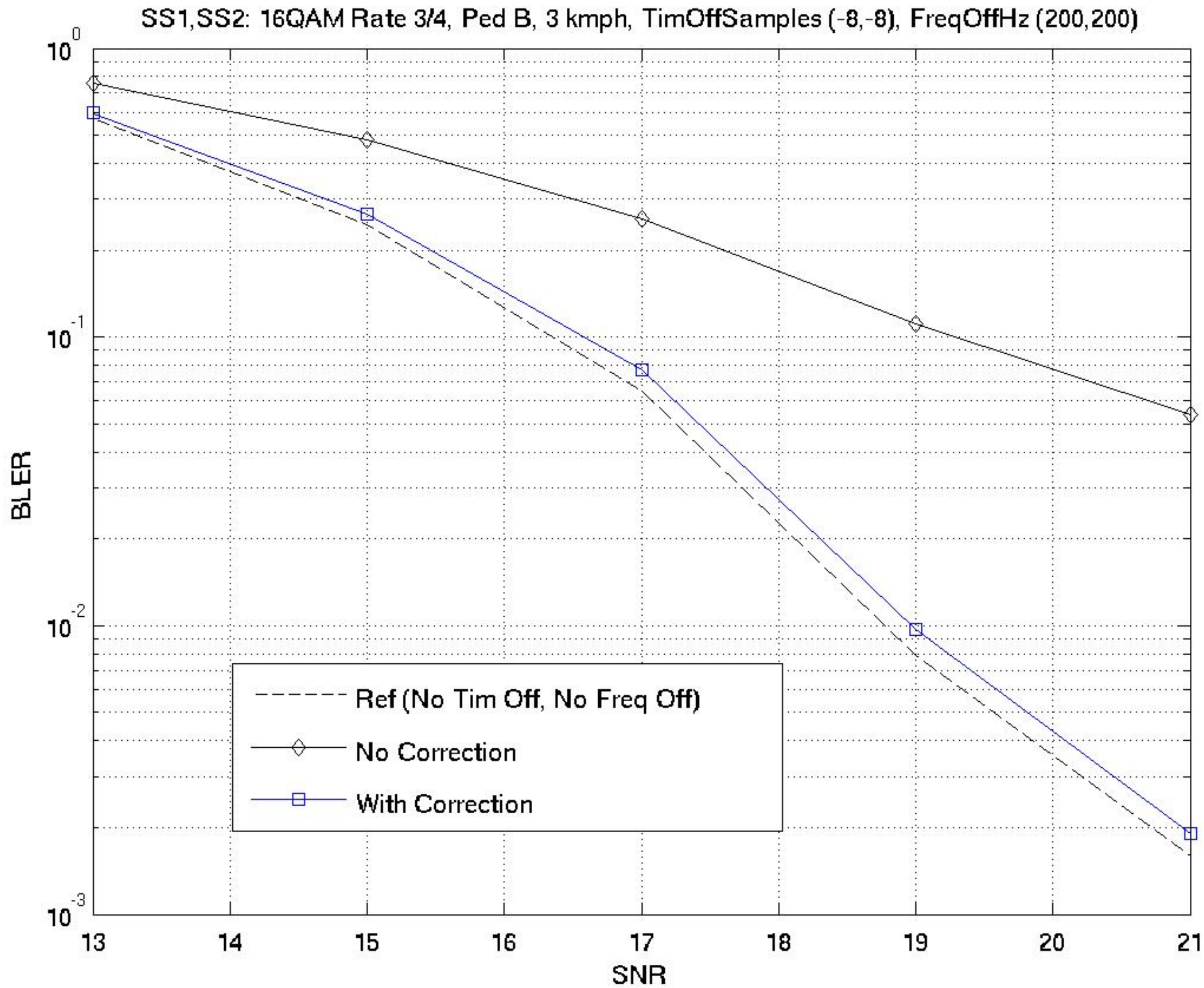
SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,200)



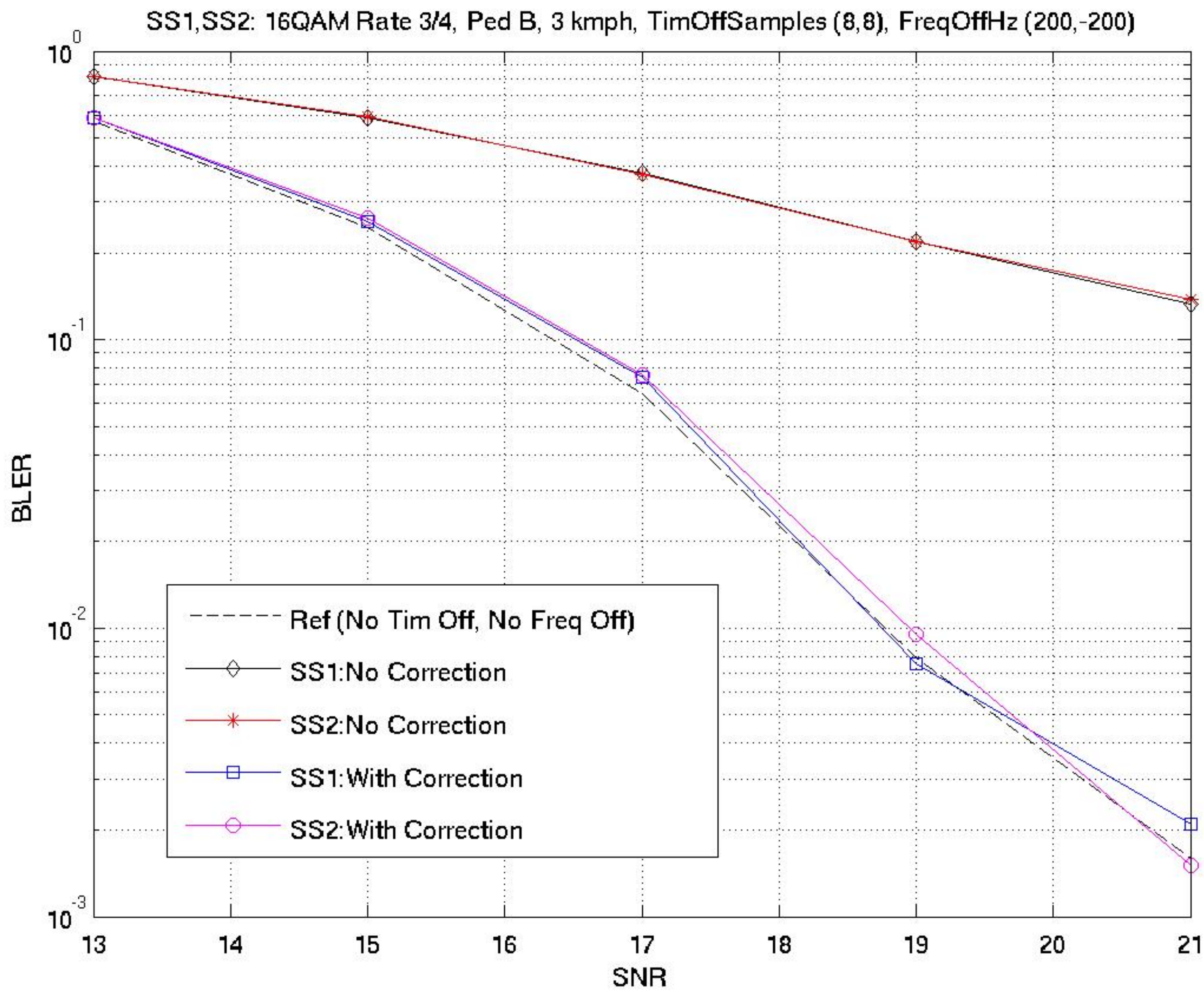
SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph
Tim Off. (Samples): (8,-8), Freq Off. (Hz): (200,200)



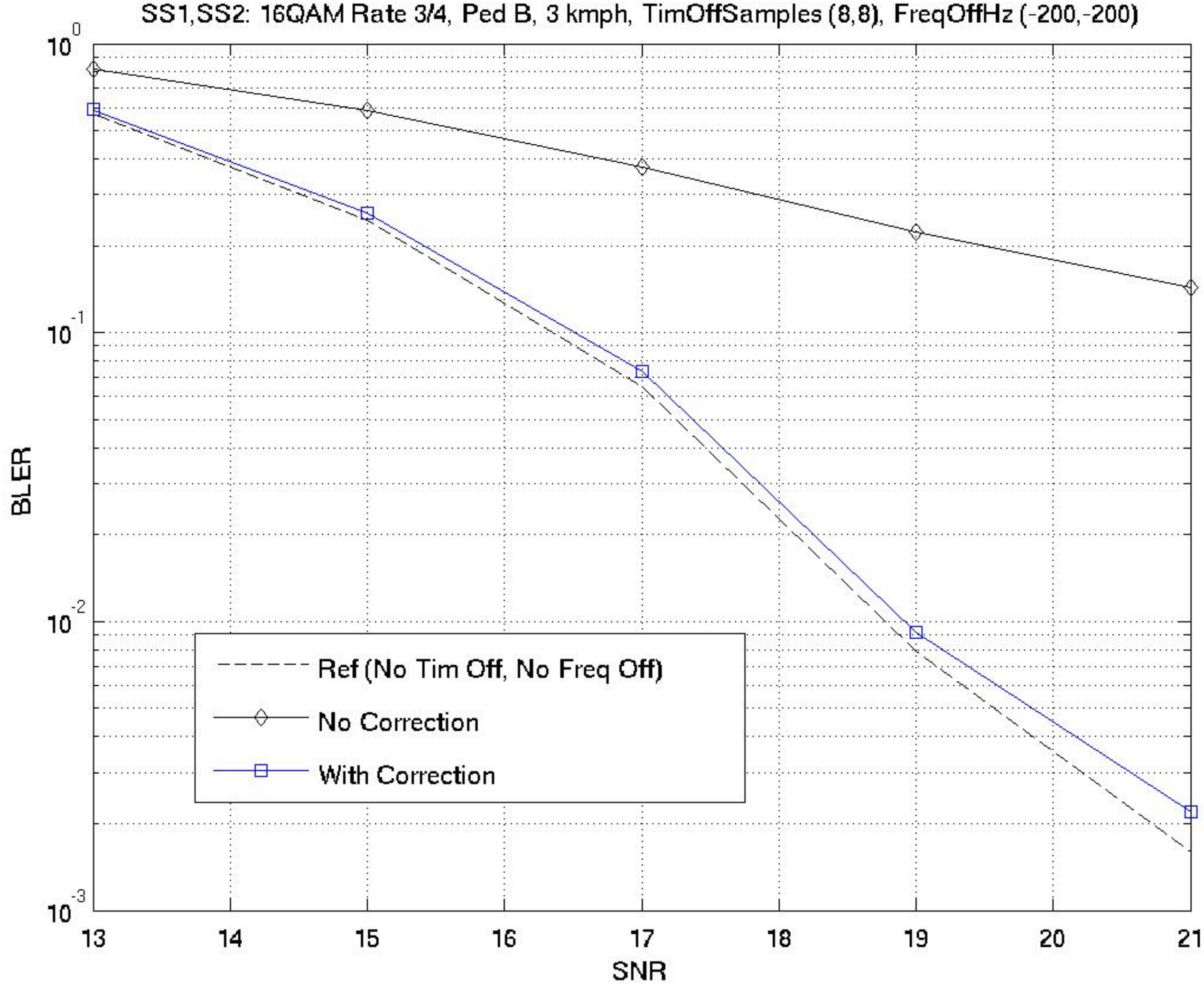
SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph Tim Off. (Samples): (-8,-8), Freq Off. (Hz): (200,200)



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)

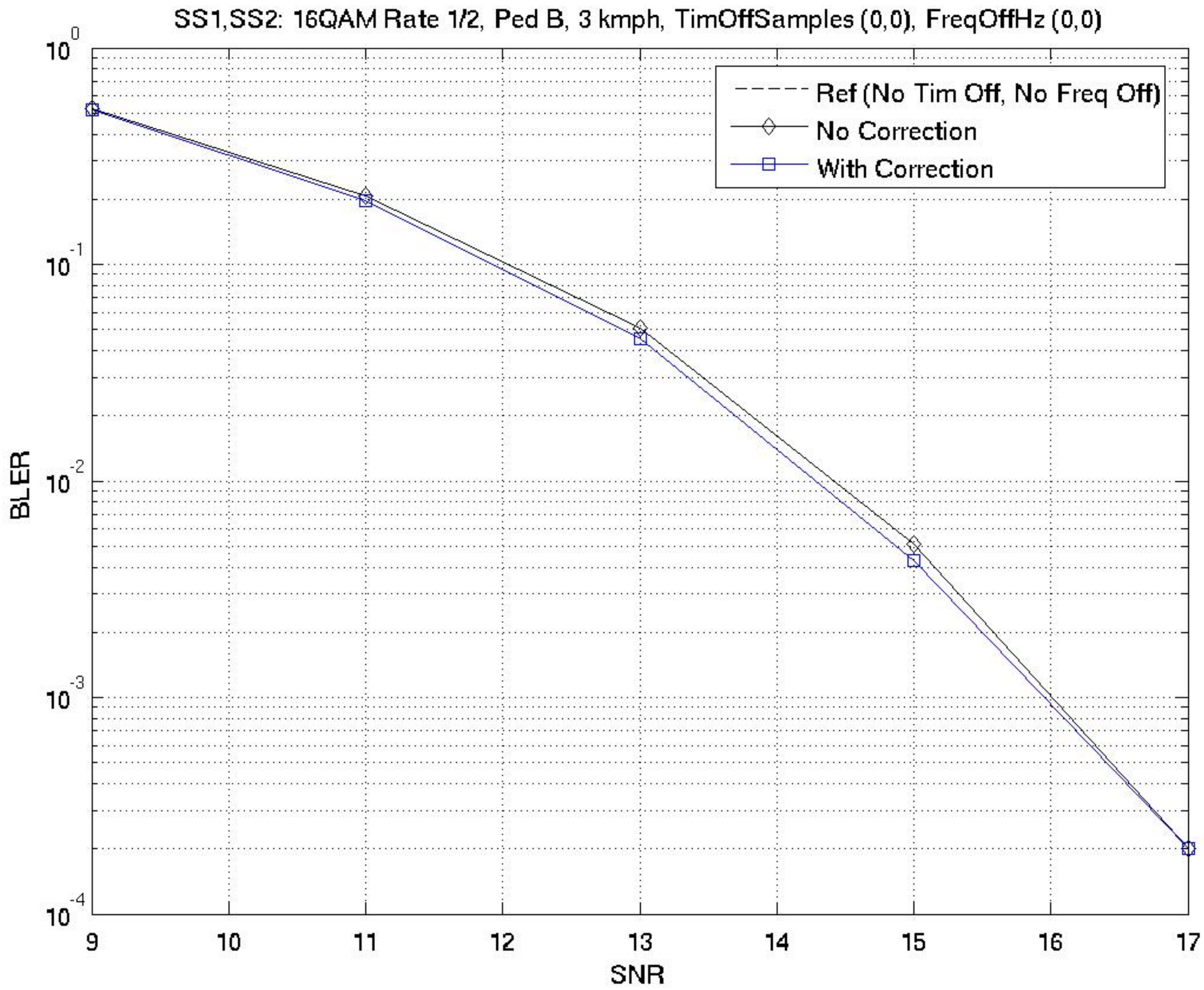


Simulation Scenario II

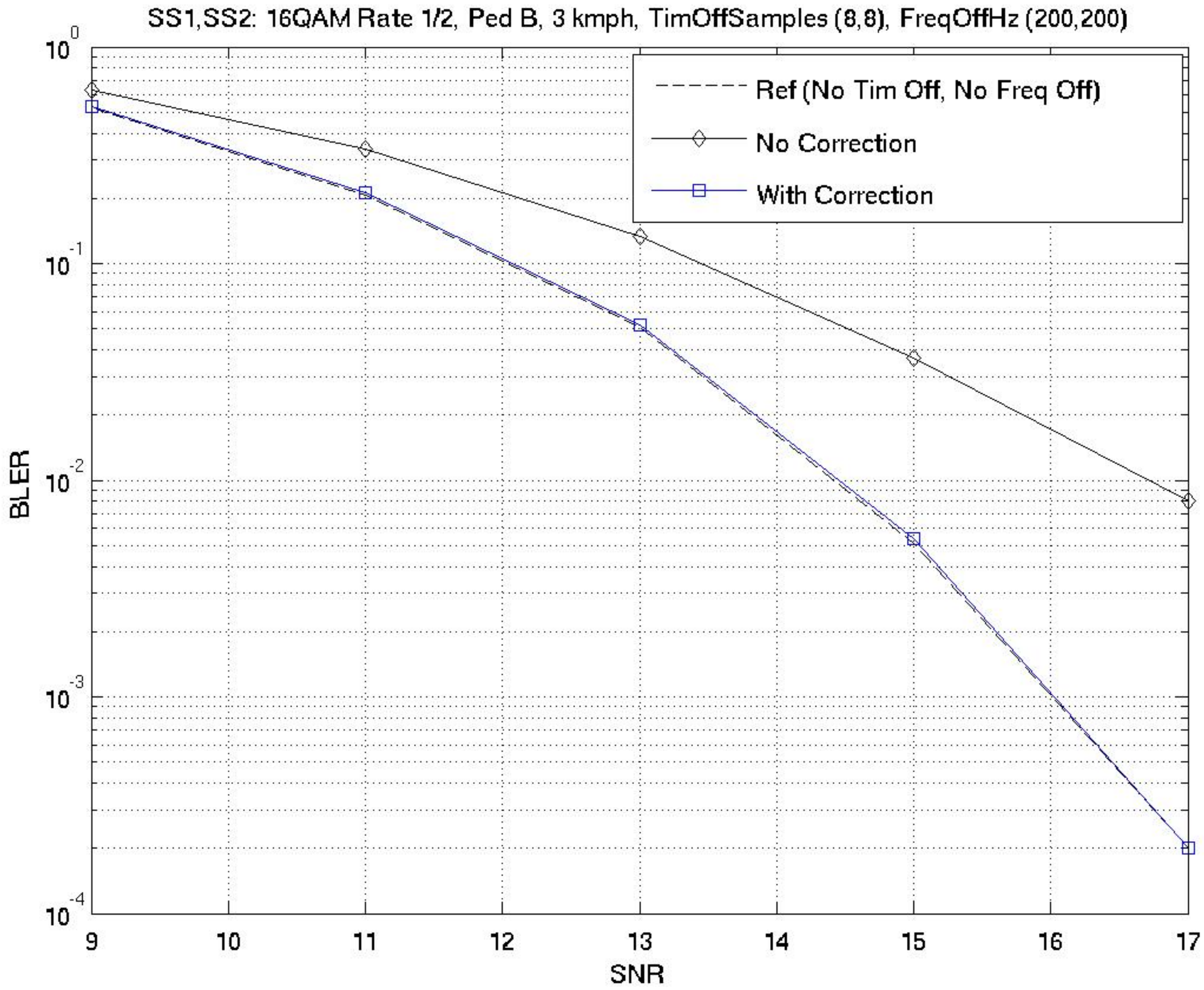
- SS#1, SS#2: 16QAM Rate ½, Ped B, 3 kmph.

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

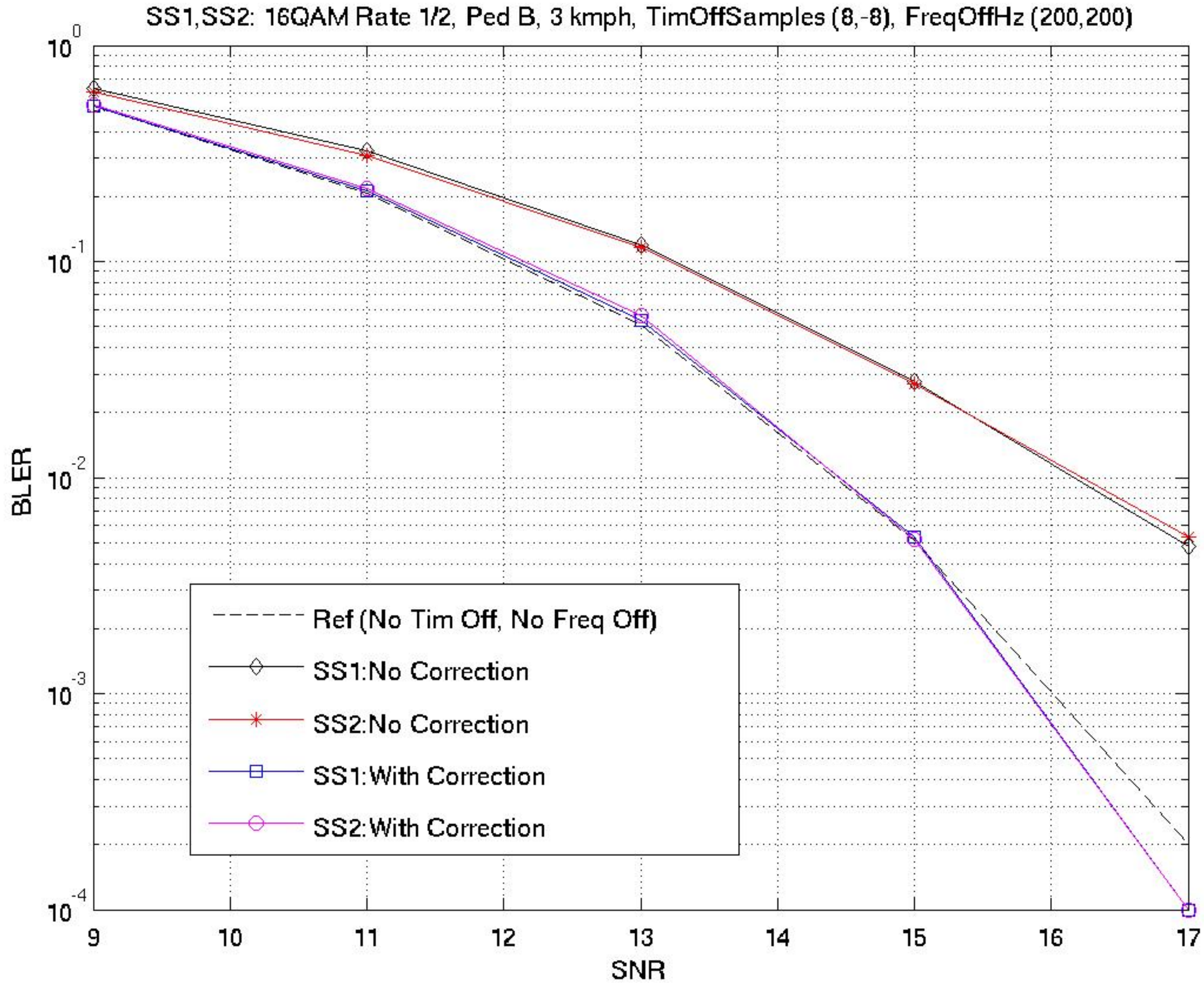
SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph
Tim Off. (Samples): (0,0), Freq Off. (Hz): (0,0)



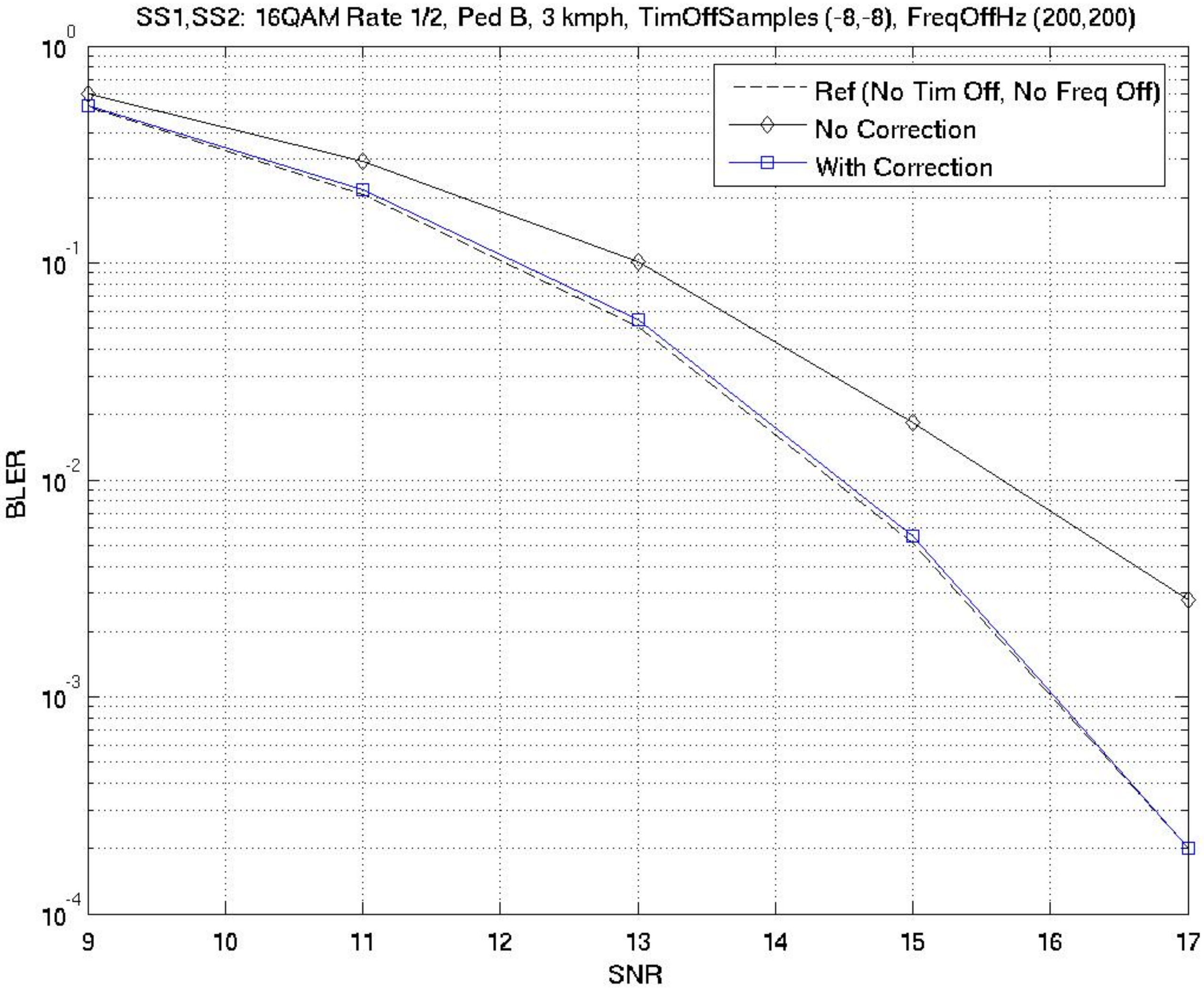
SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,200)



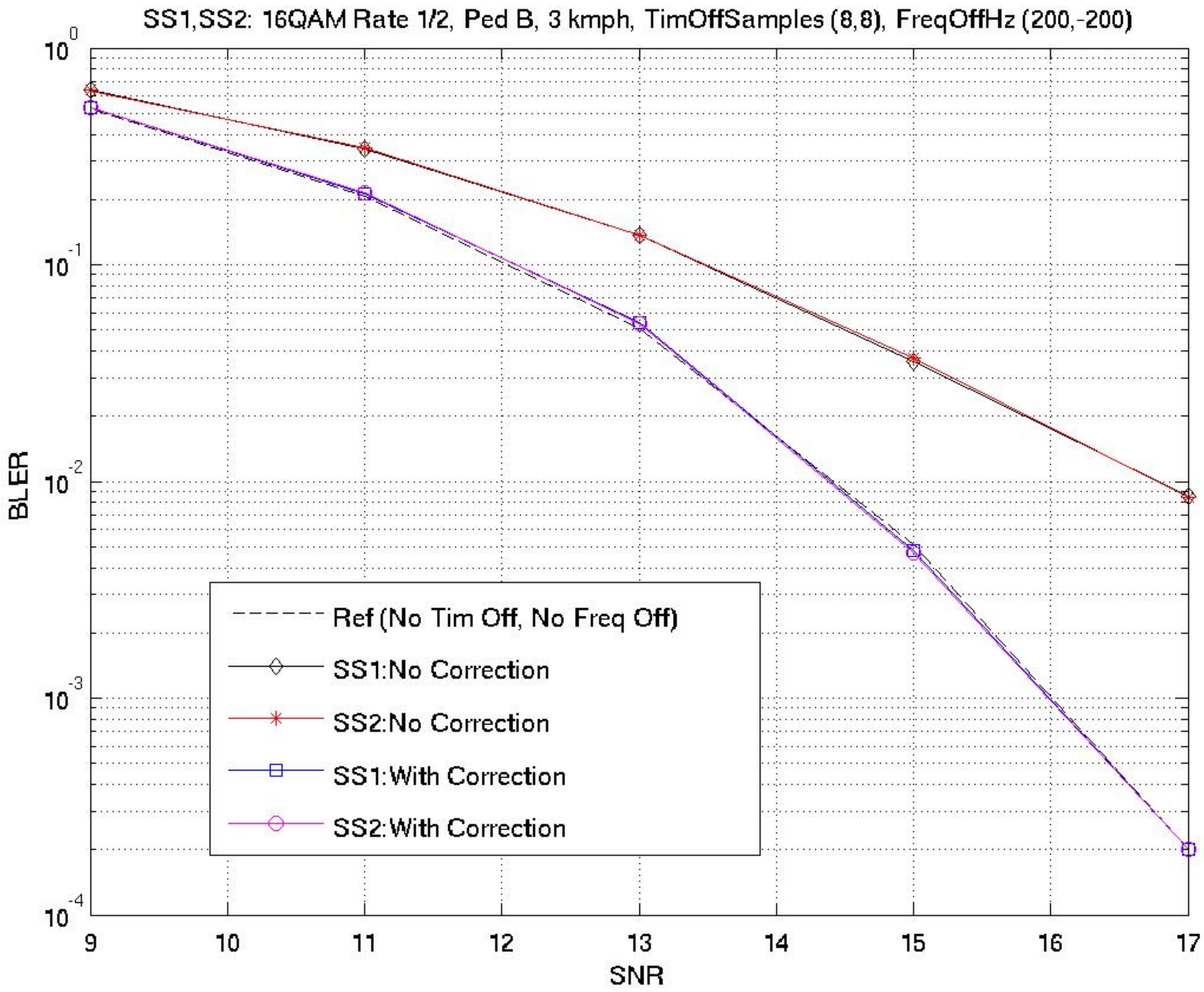
SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph
Tim Off. (Samples): (8,-8), Freq Off. (Hz): (200,200)



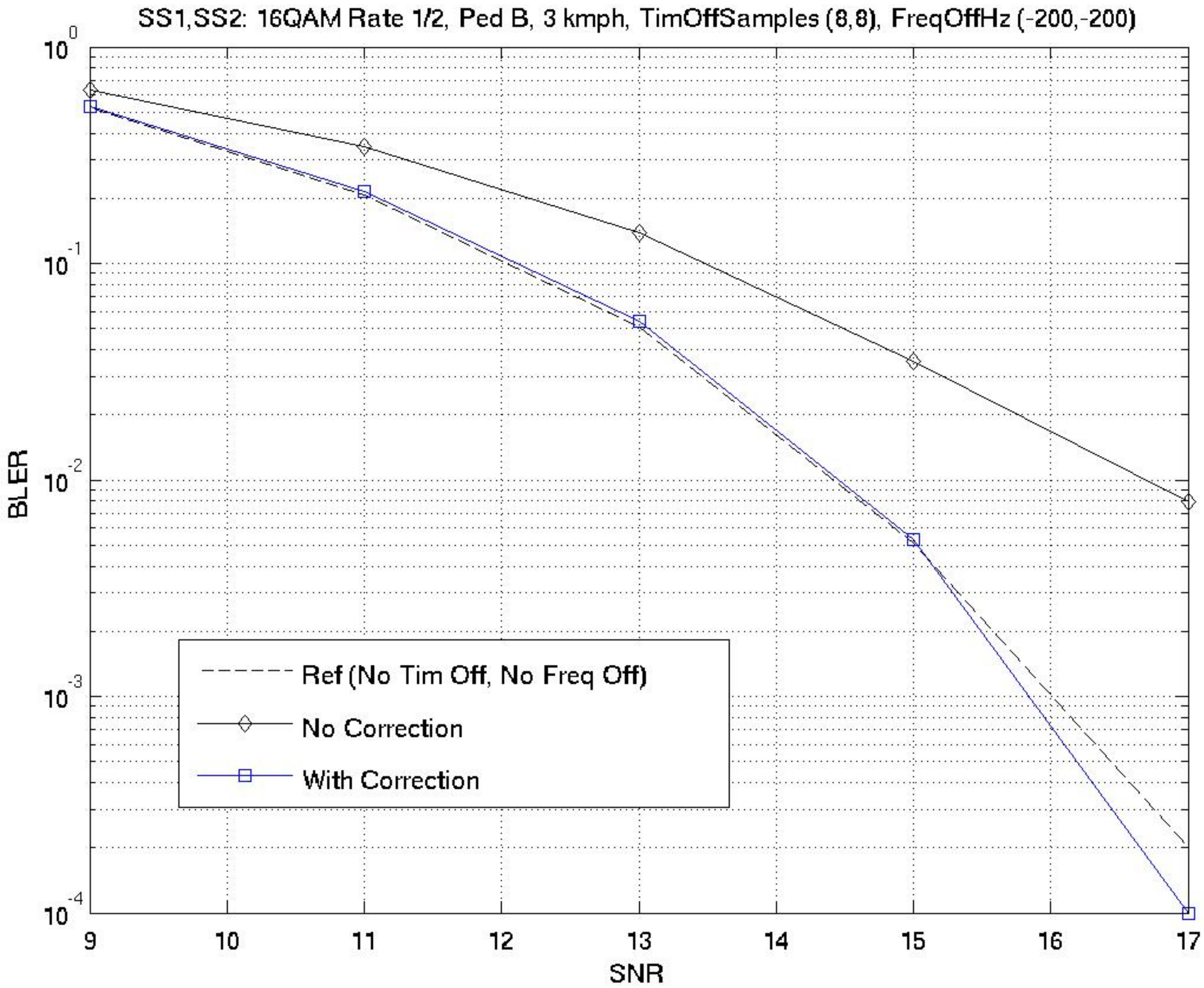
SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph Tim Off. (Samples): (-8,-8), Freq Off. (Hz): (200,200)



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)

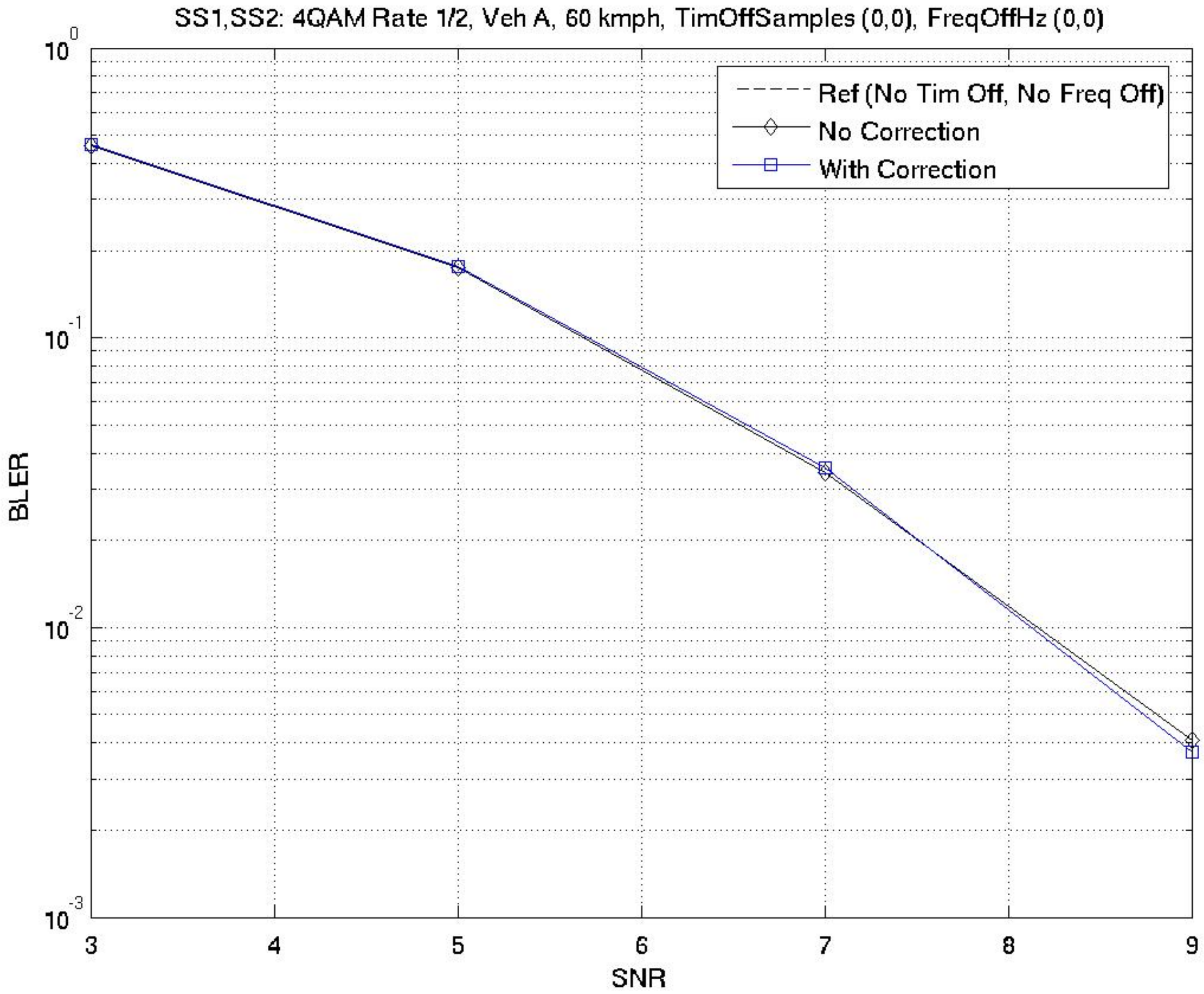


Simulation Scenario III

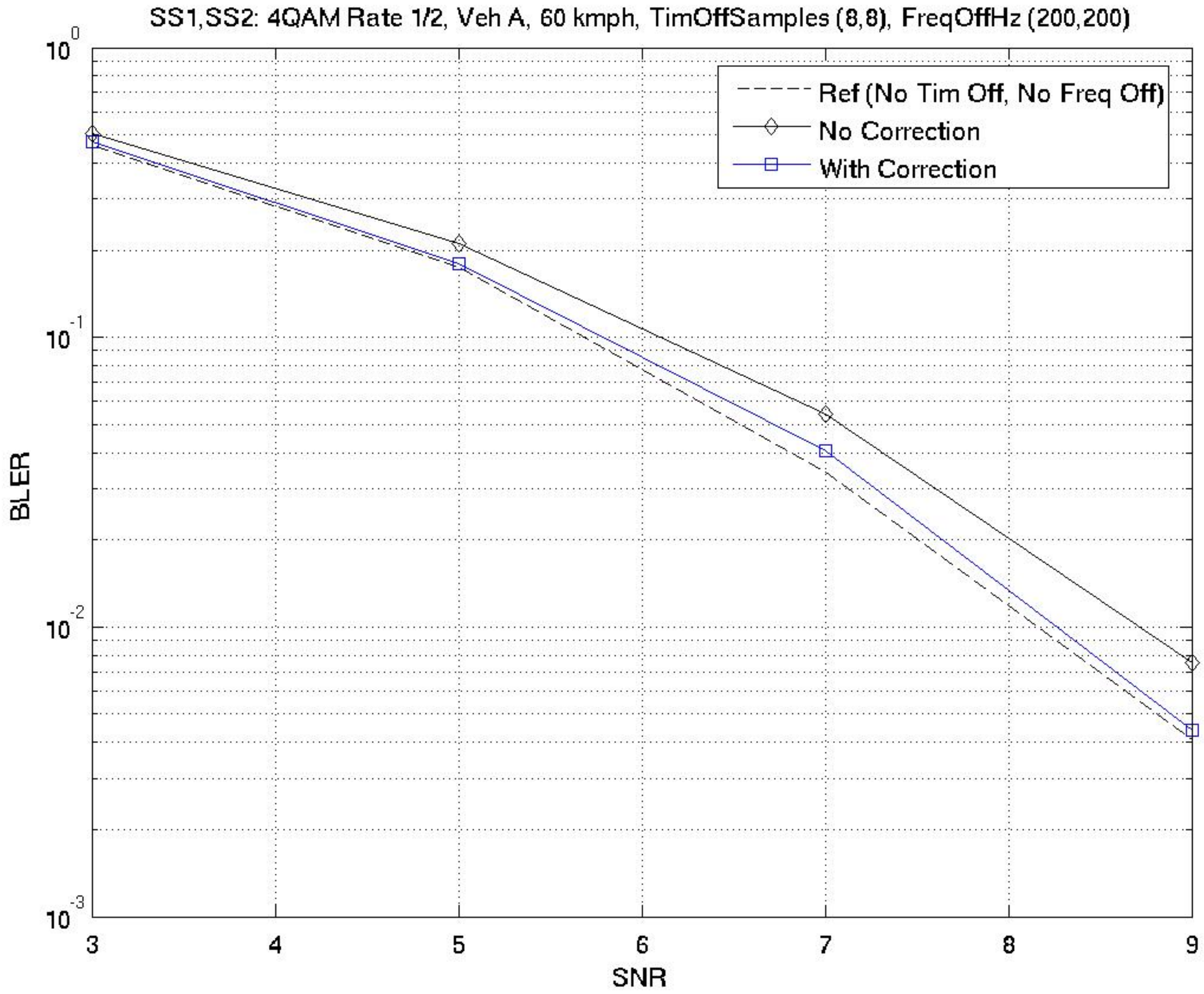
- SS#1, SS#2: 4QAM Rate ½, Veh A, 60 kmph.

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

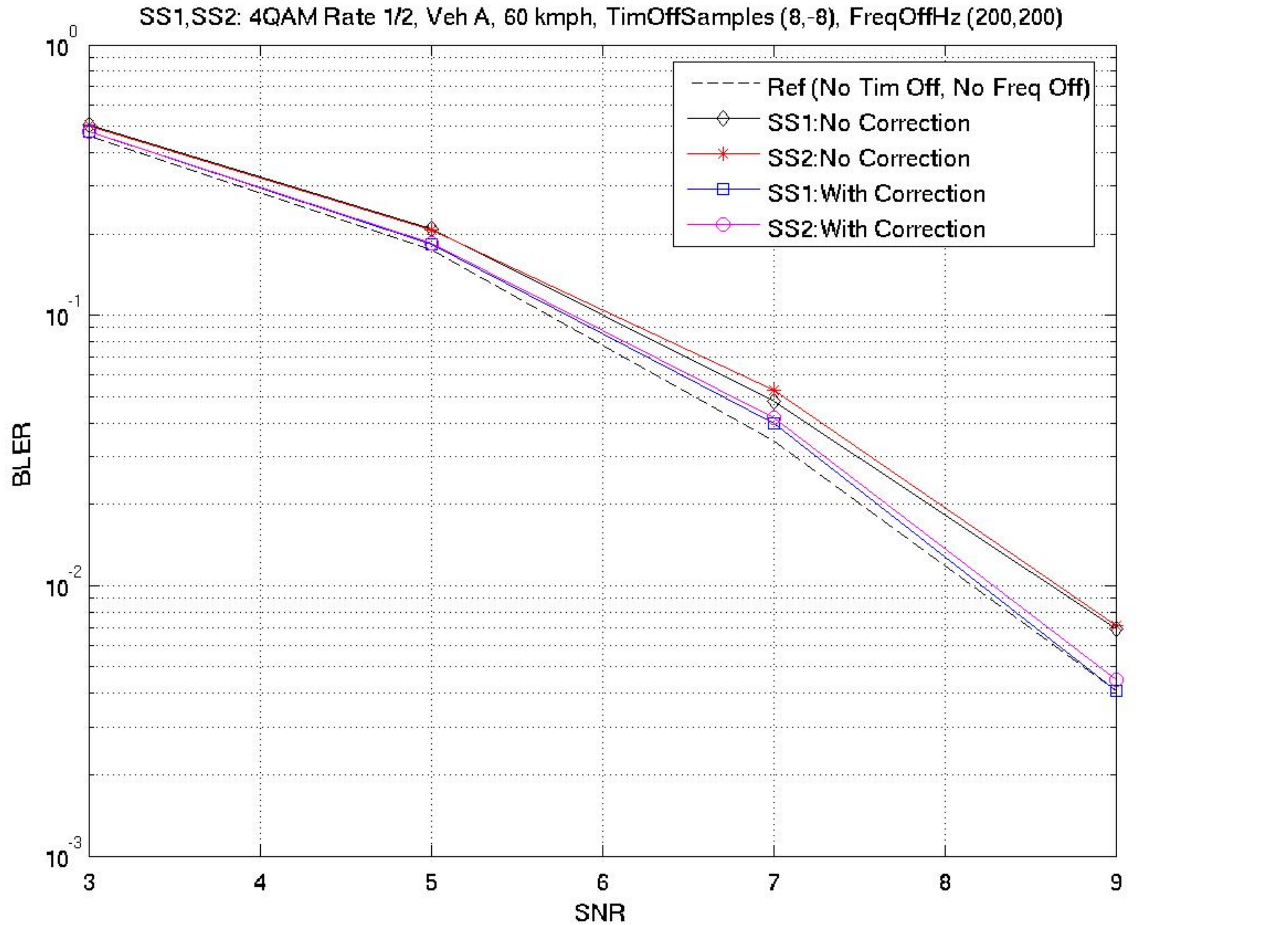
SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph Tim Off. (Samples): (0,0), Freq Off. (Hz): (0,0)



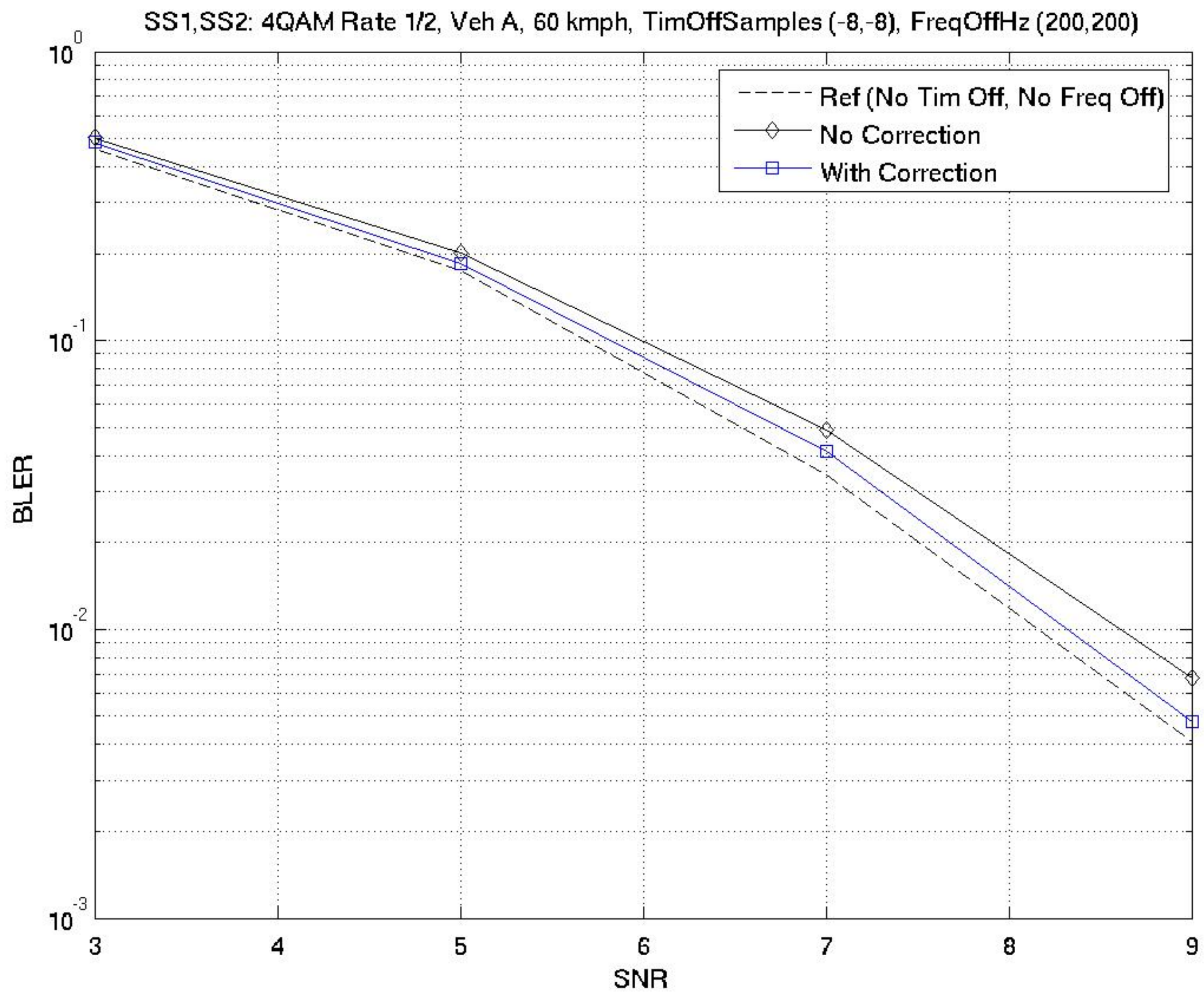
SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,200)



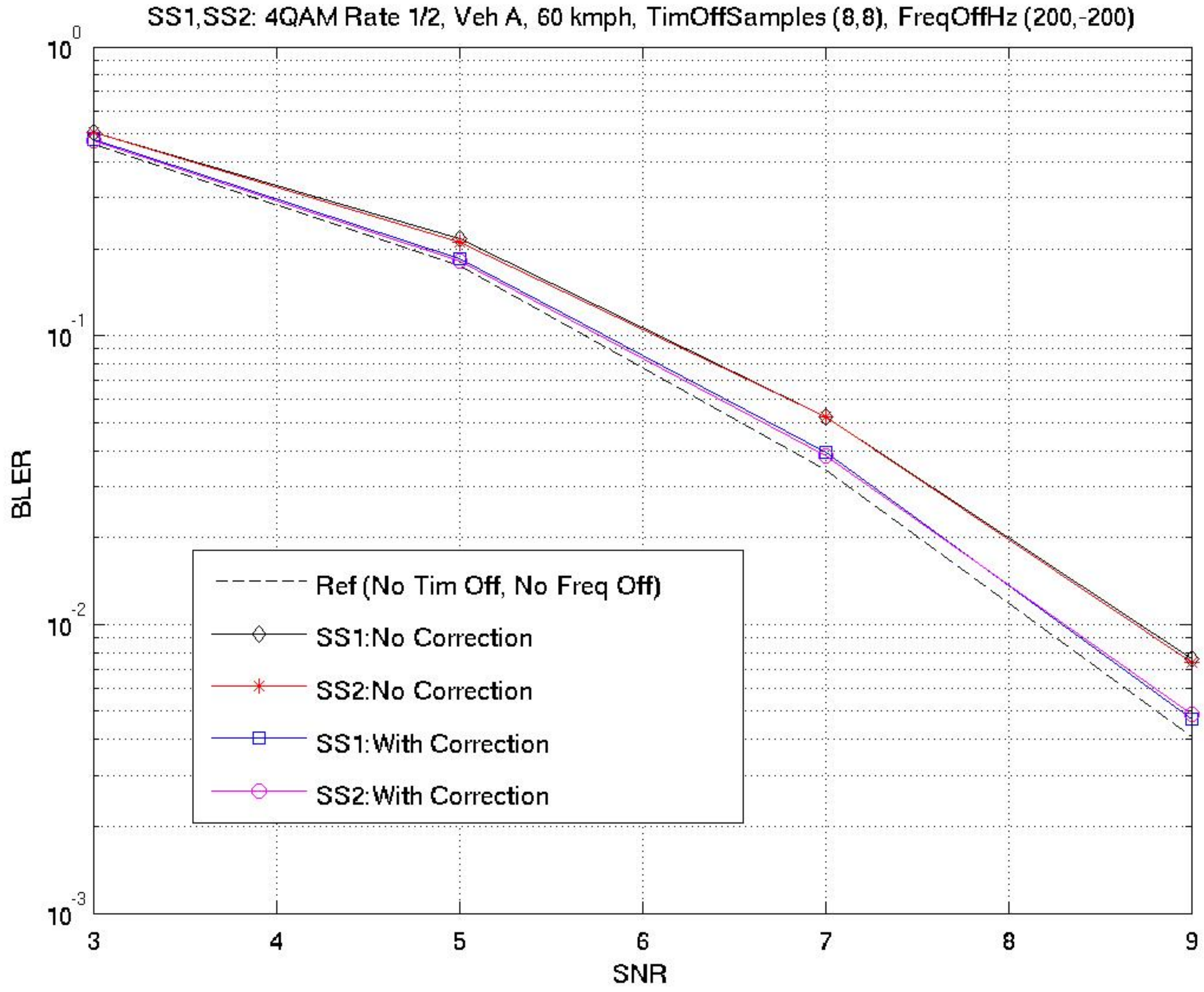
SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph
Tim Off. (Samples): (8,-8), Freq Off. (Hz): (200,200)



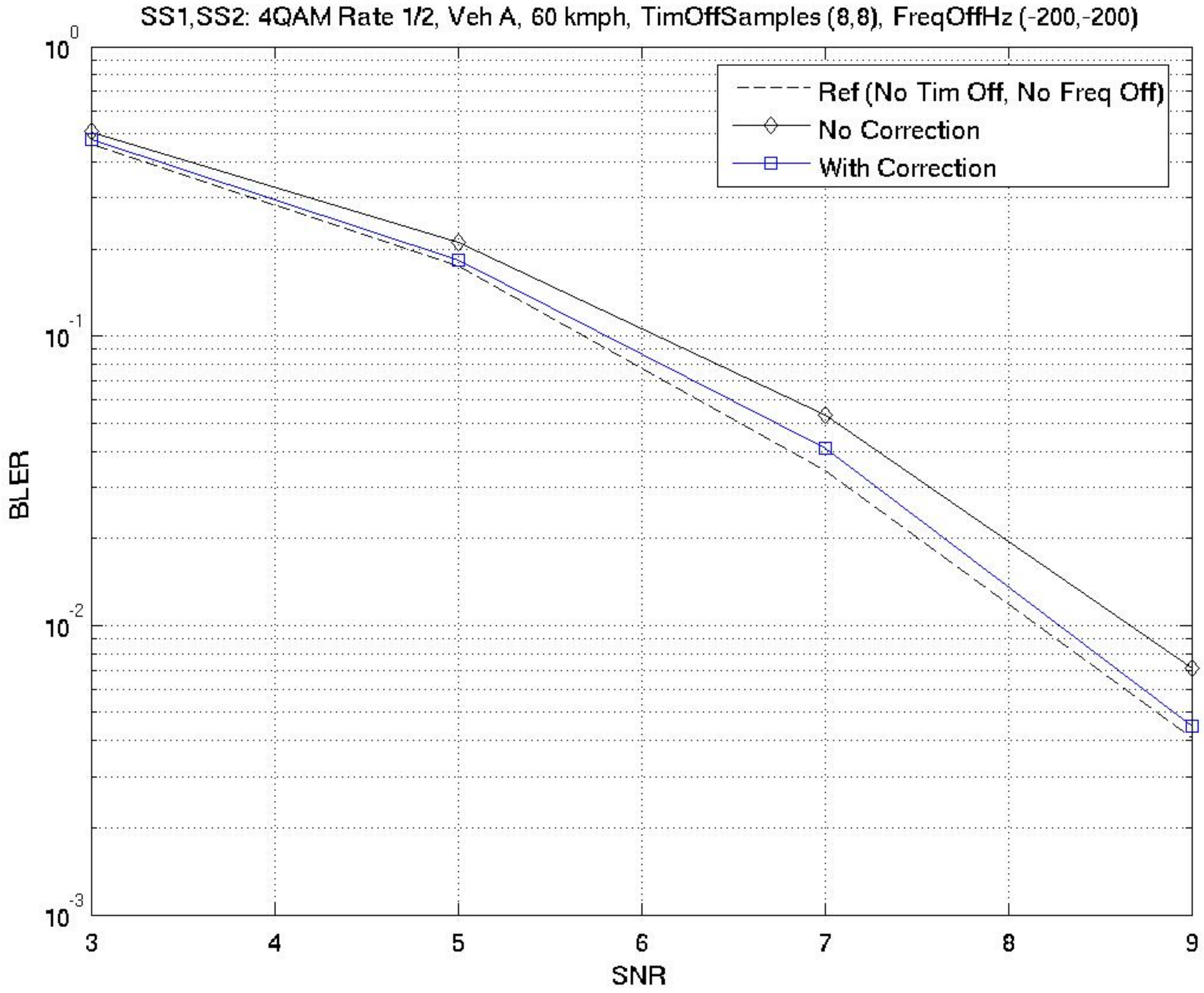
SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph
Tim Off. (Samples): (-8,-8), Freq Off. (Hz): (200,200)



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 $t = \mathrm{mod}(s+k,2)$