

**IEEE 802.16 Presentation Submission Template (Rev. 9)**

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Louay Jalloul  
Beceem Communications Inc.

Voice: +1.408.387.5048

E-mail: [jalloul@beceem.com](mailto:jalloul@beceem.com)

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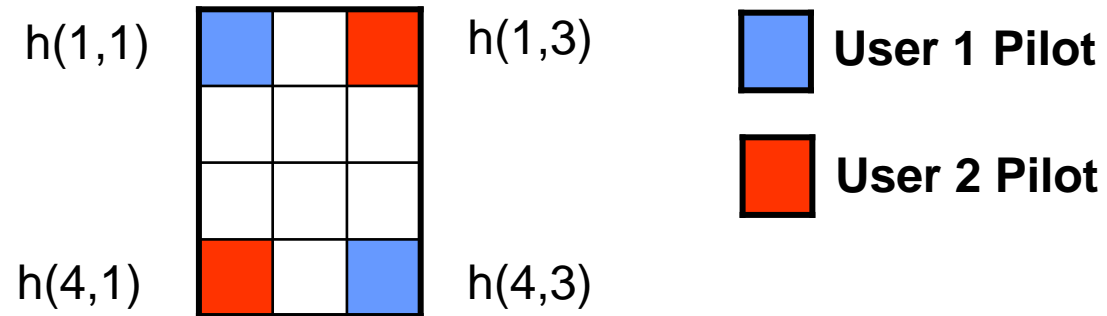
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The contributor is familiar with the IEEE-SA Patent Policy and Procedures:

<http://standards.ieee.org/guides/bylaws/sect6-7.html#6>> and <http://standards.ieee.org/guides/opman/sect6.html#6.3>>.

Further information is located at <http://standards.ieee.org/board/pat/pat-material.html>> and <http://standards.ieee.org/board/pat> >.

## Problem Statement: 16e UL PUSC MIMO-CSM Tile



- According to the 16e standard:
  - Timing offset is within  **$\pm 8$  samples** (  $\Delta\tau$  )
  - Frequency offset is assumed to be  **$\pm 200$  Hz** (  $\Delta f$  , 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

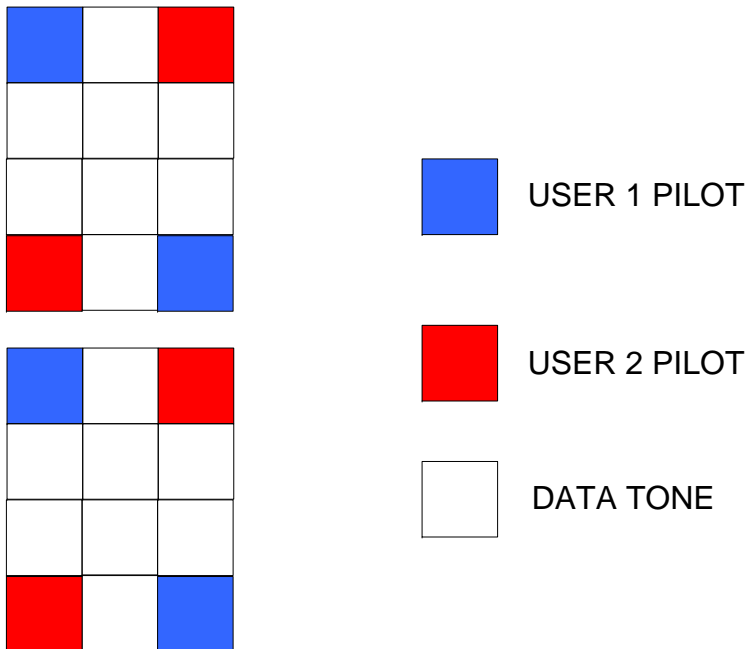
$$y_{i,p}(k,l) = \exp\left[j(\theta(k,l))\right] h_{i,p}(k,l) x_p(k,l) + u_{i,p}(k,l)$$

- 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

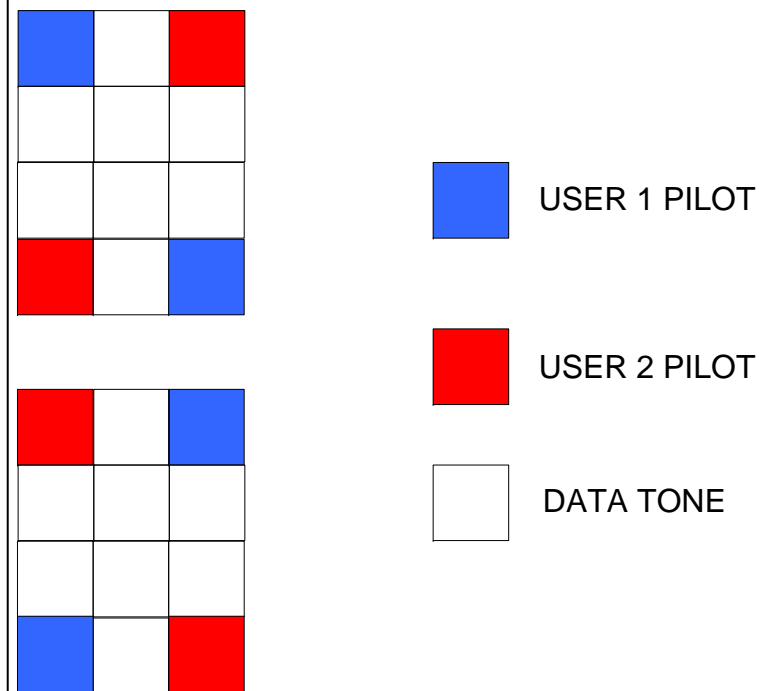
## ➤ 16e UL PUSC MIMO-CSM Tile

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



## ➤ New UL PUSC 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 ( $\theta_t$ ) from the phase contribution due to frequency offset ( $\theta_f$ ) 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

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

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

## 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

$$\theta_t = \frac{1}{4} \angle (z_p z_{p+1})$$

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

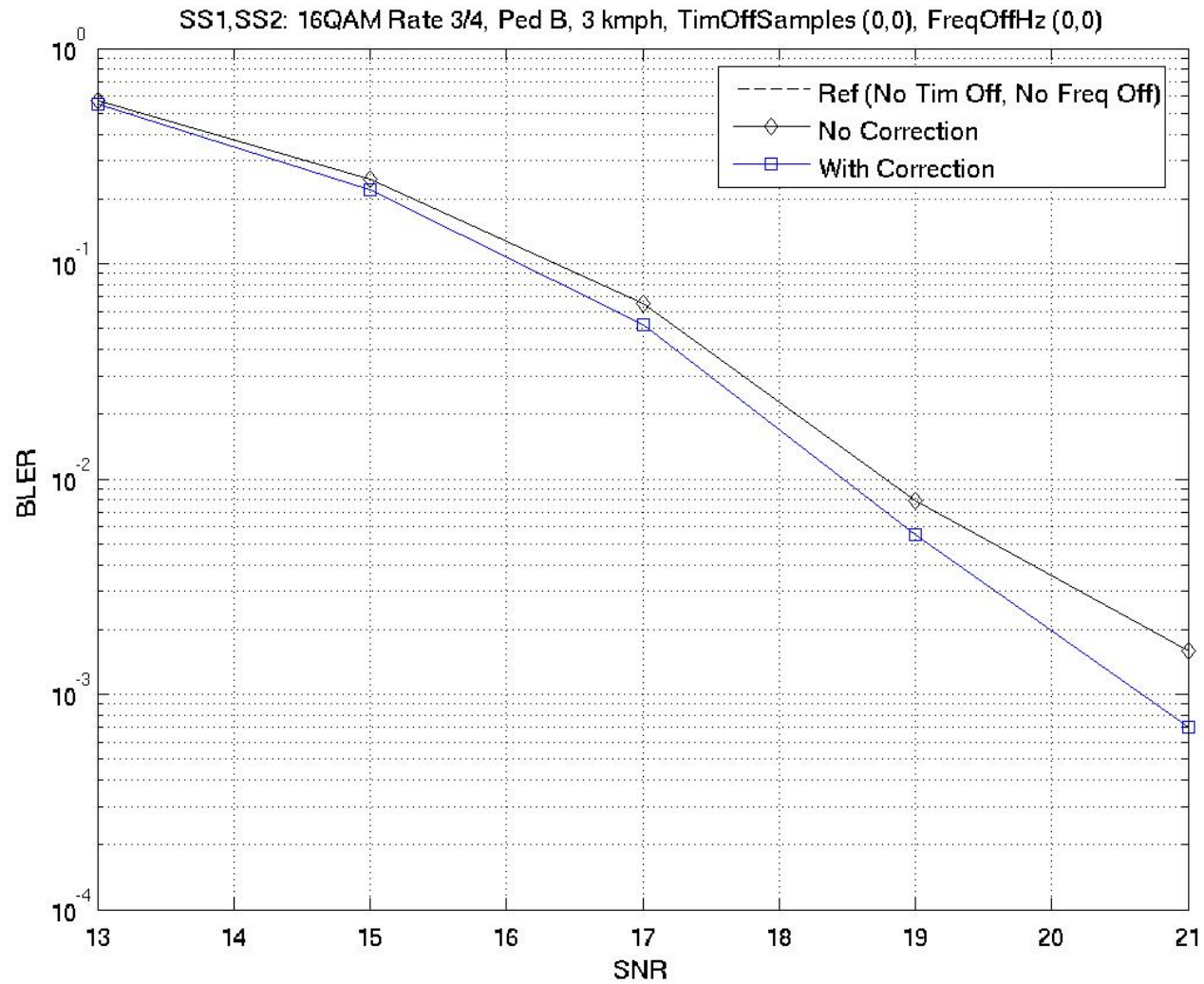
- The estimates of the phase contribution due timing offset and phase contribution due to frequency offset shown in this example are from a pair of tiles and a single antenna. These estimates can be improved using multiple tiles and multiple antennas
  - Tiles in sub-channels are used to improve the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

# Simulation Scenario I

- SS#1, SS#2: 16QAM Rate  $\frac{3}{4}$ , Ped B, 3 kmph.

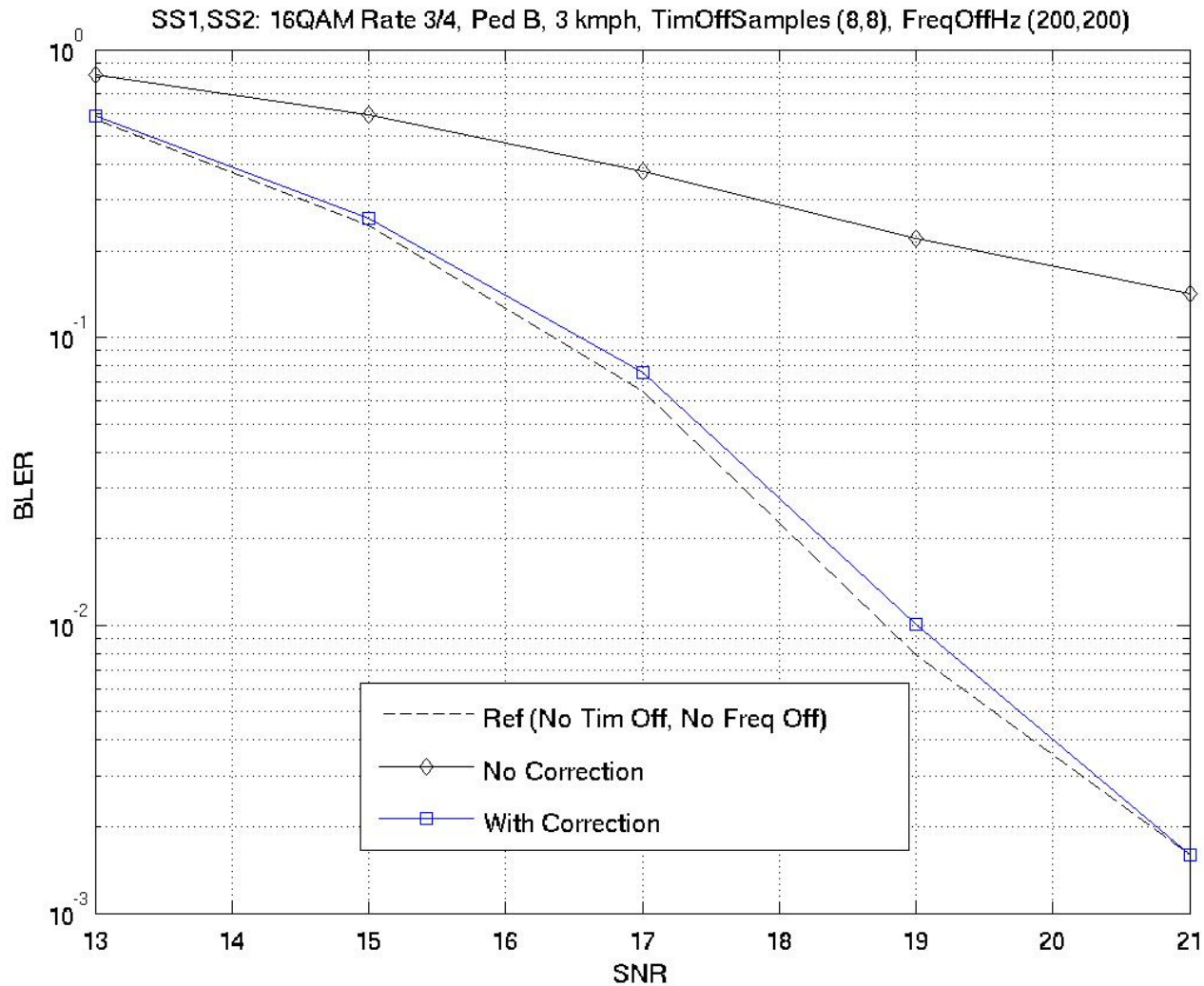
Tim. Off. SS#1 (Samples)	Tim. Off. SS#2 (Samples)	Freq. Off. SS#1 (Hz)	Freq. Off. SS#2 (Hz)
0	0	0	0
8	8	200	200
8	-8	200	200
-8	-8	200	200
8	8	200	-200
8	8	-200	-200

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

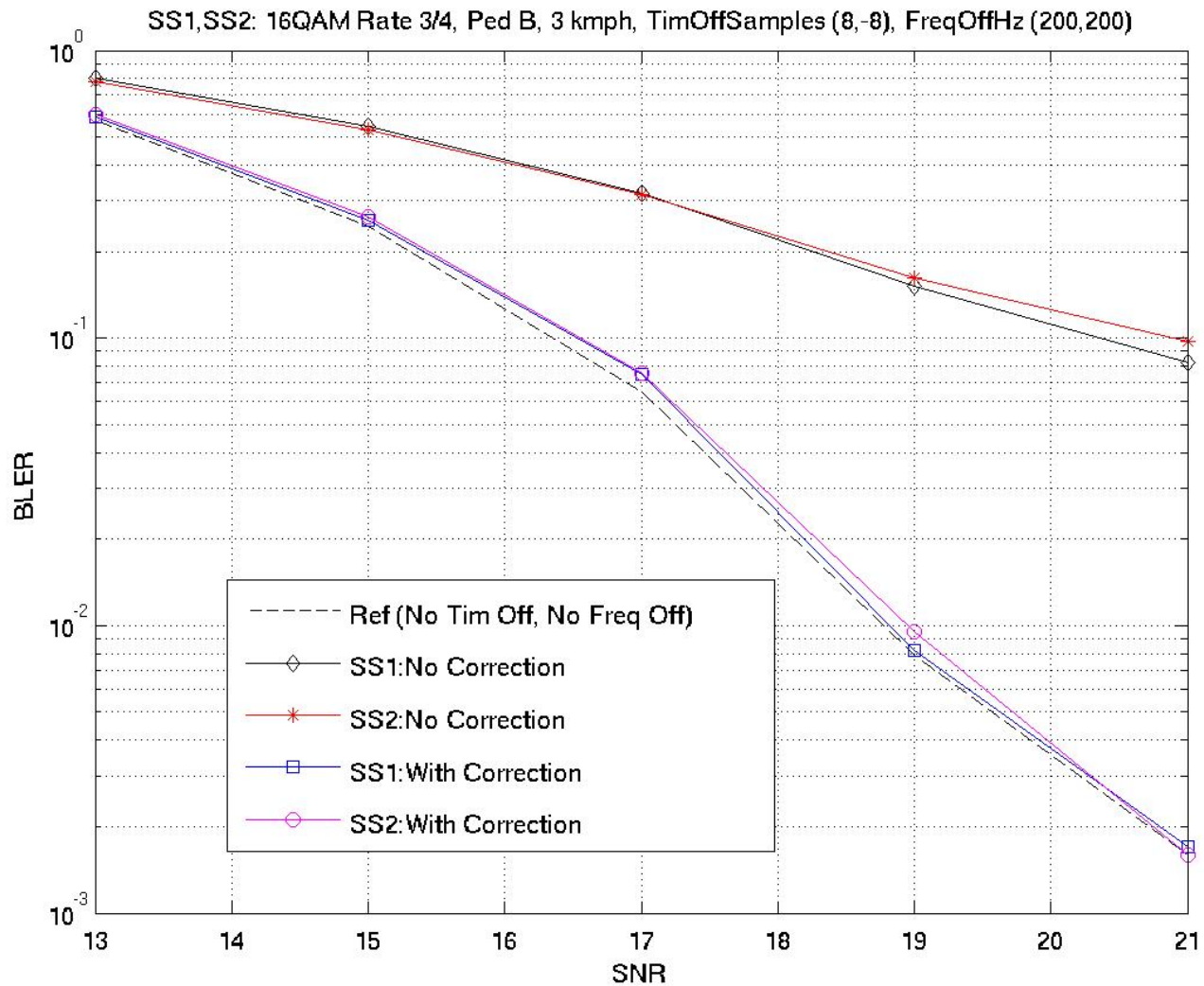




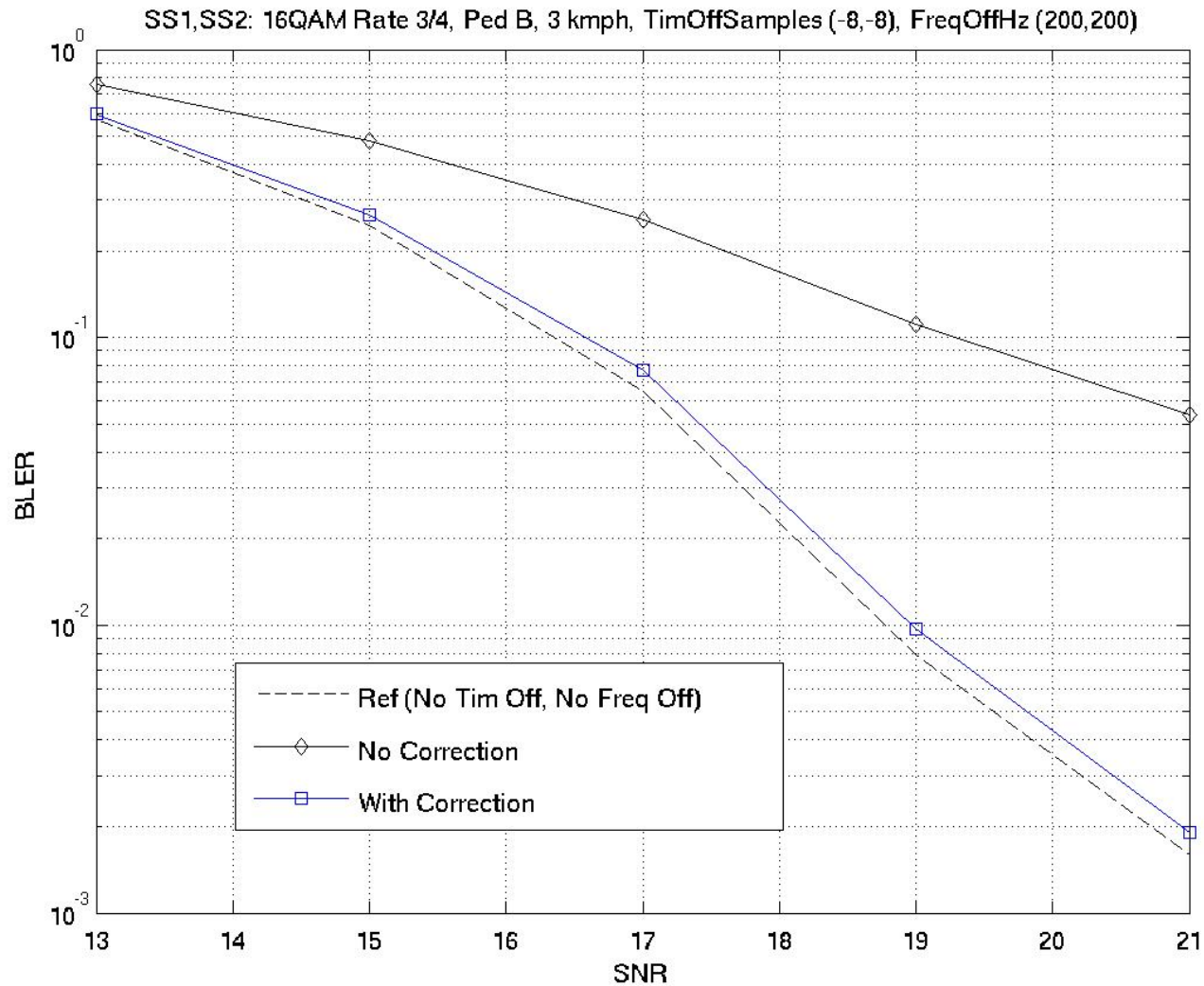
# SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,200)



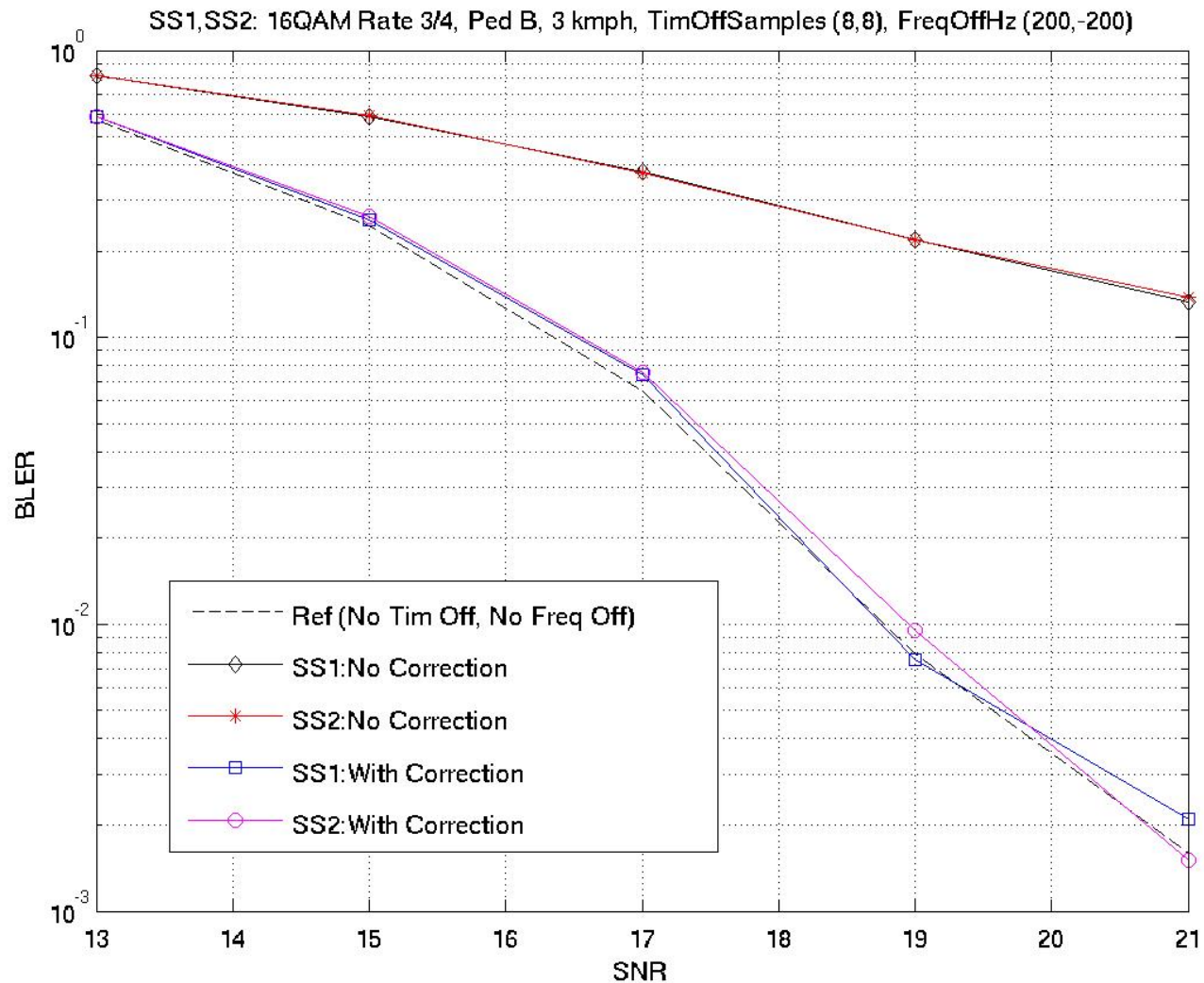
# SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph Tim Off. (Samples): (8,-8), Freq Off. (Hz): (200,200)



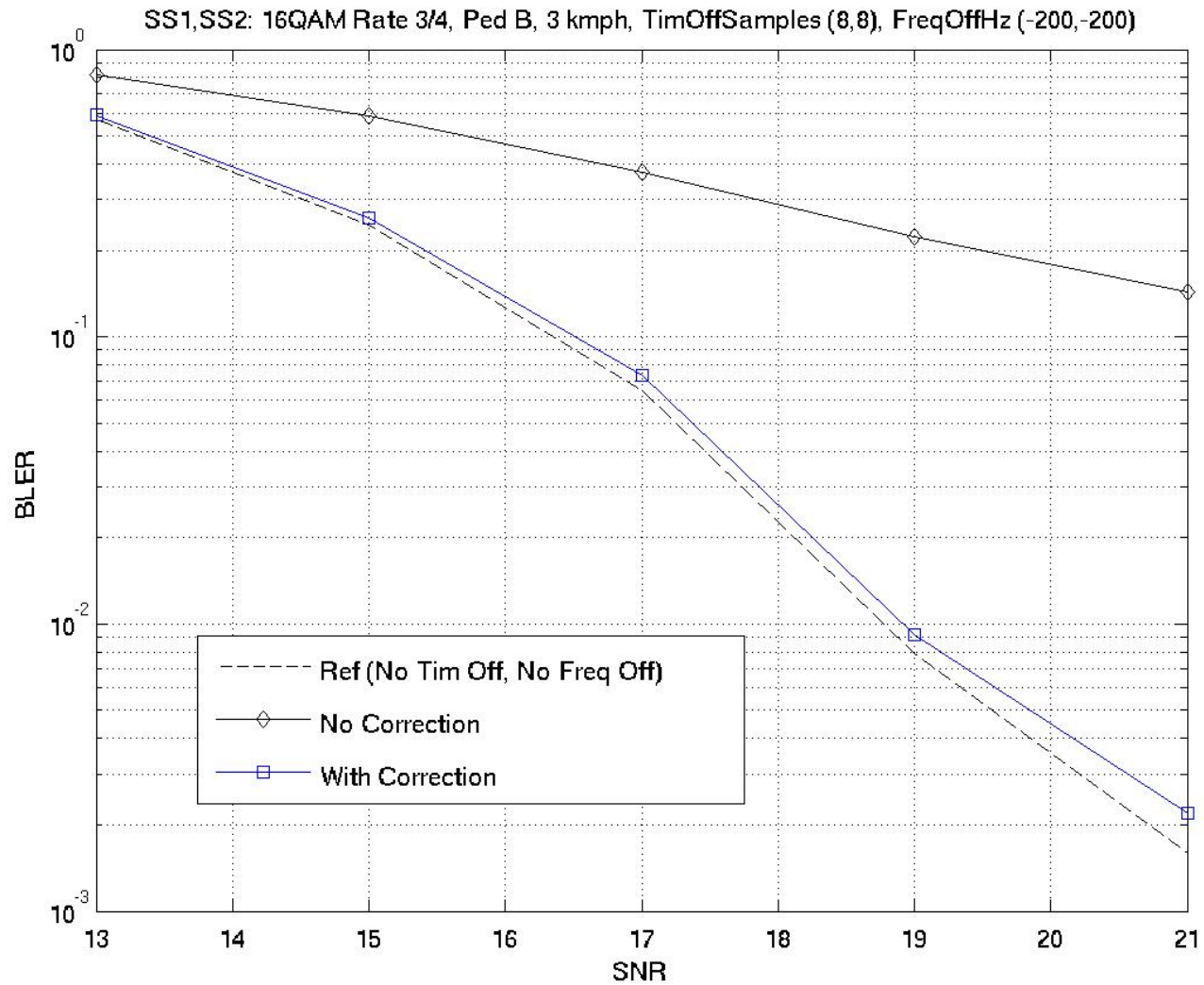
# SS #1, SS #2: 16QAM 3/4, Ped B, 3 kmph Tim Off. (Samples): (-8,-8), Freq Off. (Hz): (200,200)



# 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)

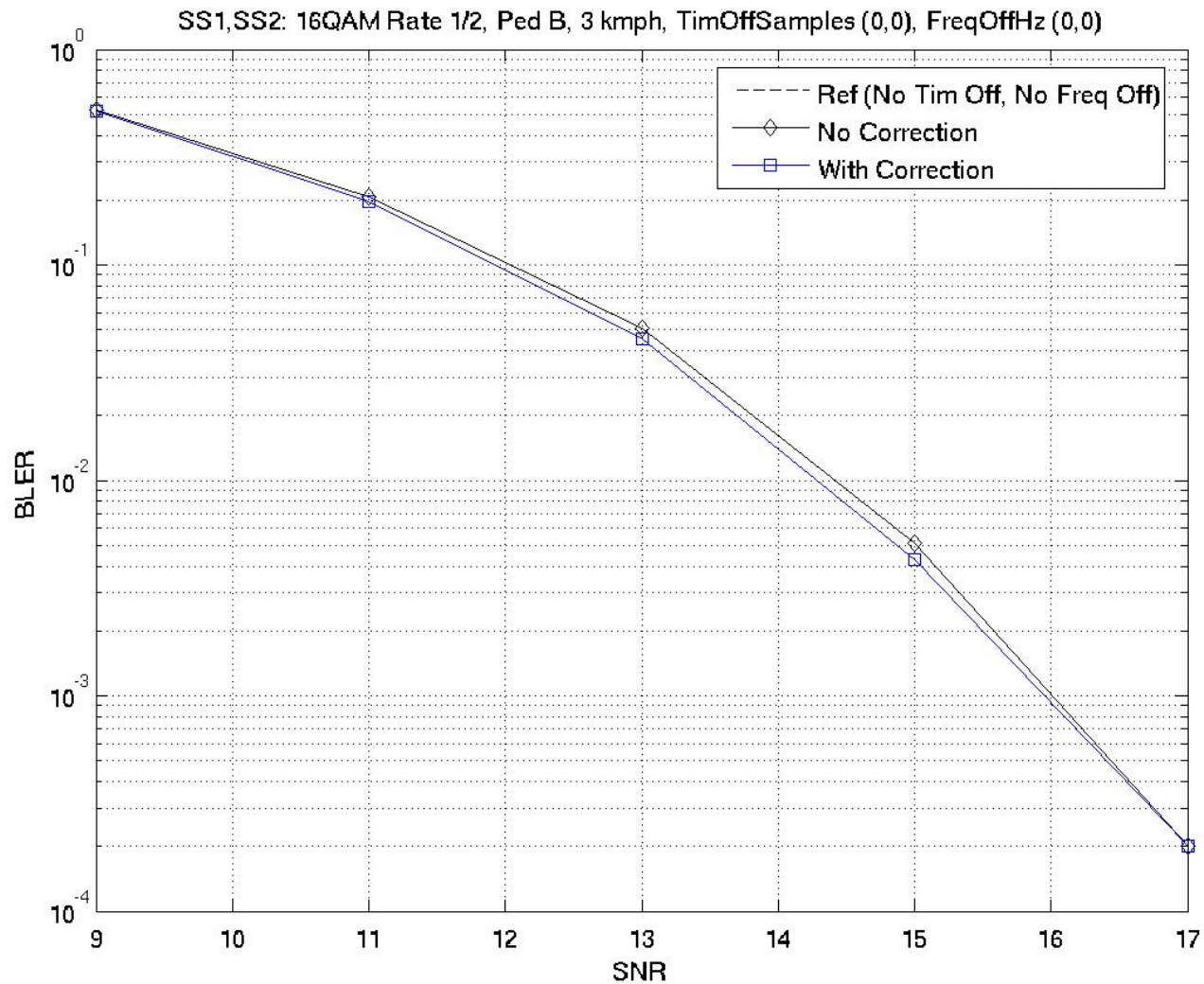


## Simulation Scenario II

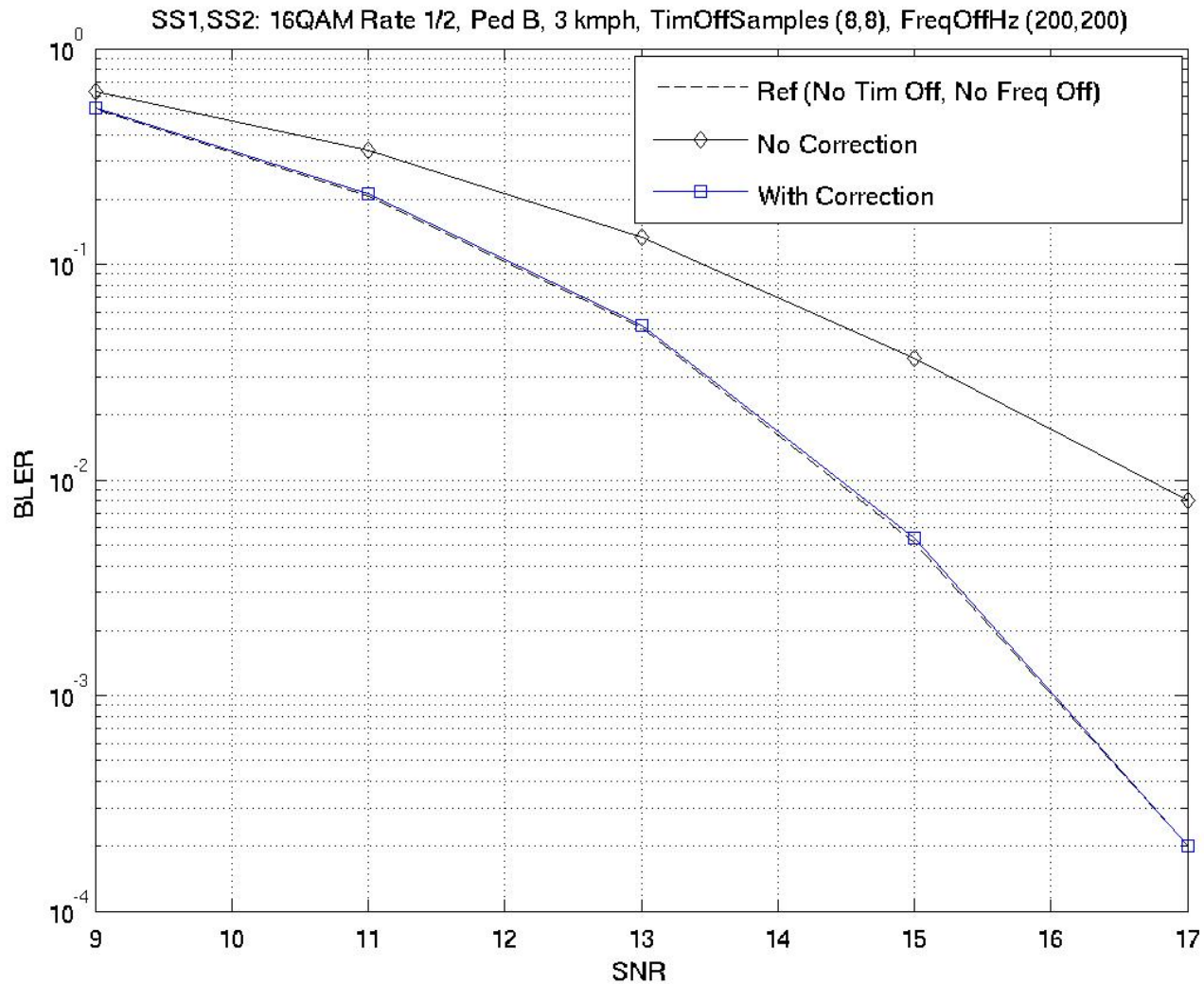
- SS#1, SS#2: 16QAM Rate  $\frac{1}{2}$ , Ped B, 3 kmph.

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)

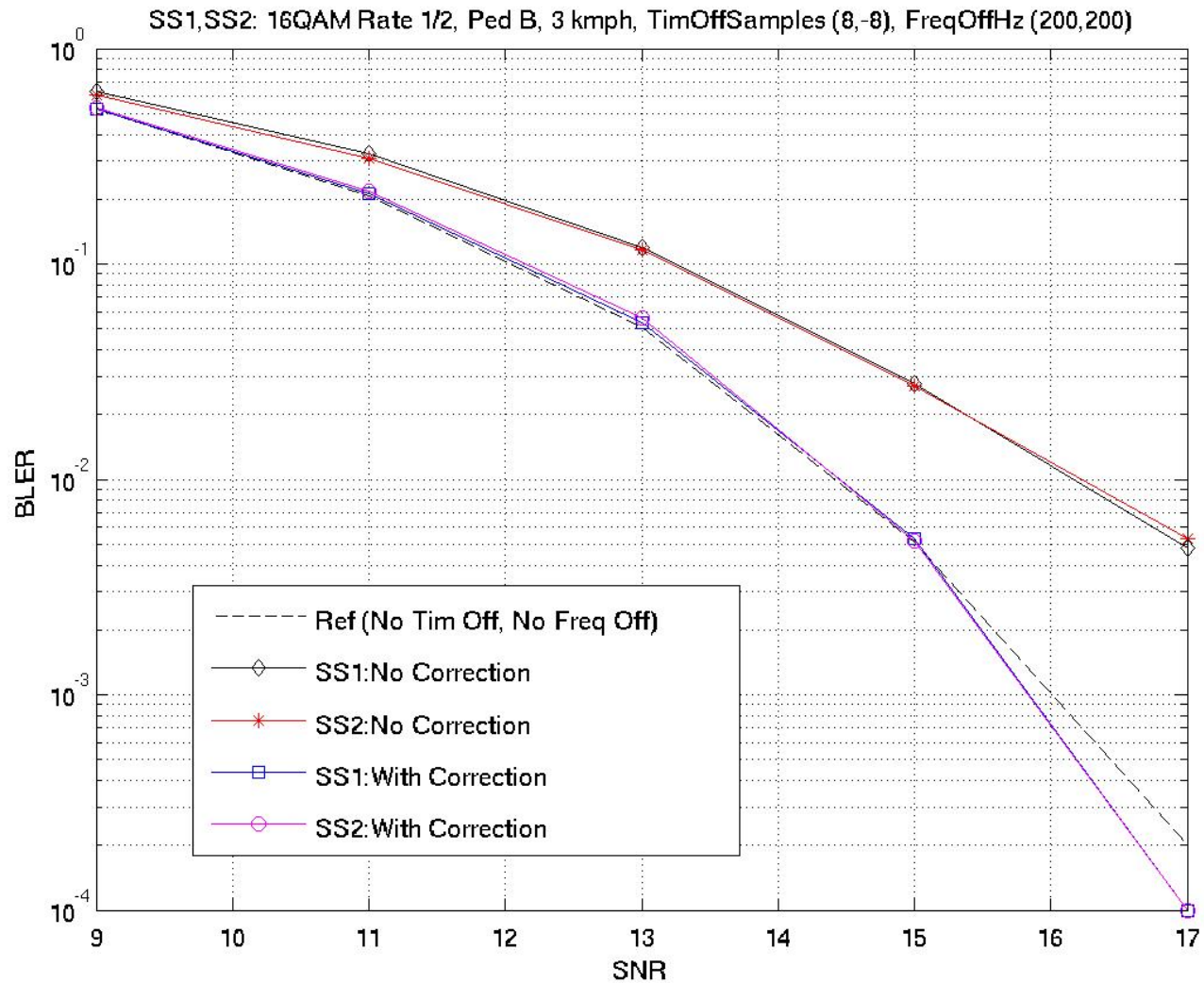


# SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph Tim Off. (Samples): (8,8), Freq Off. (Hz): (200,200)



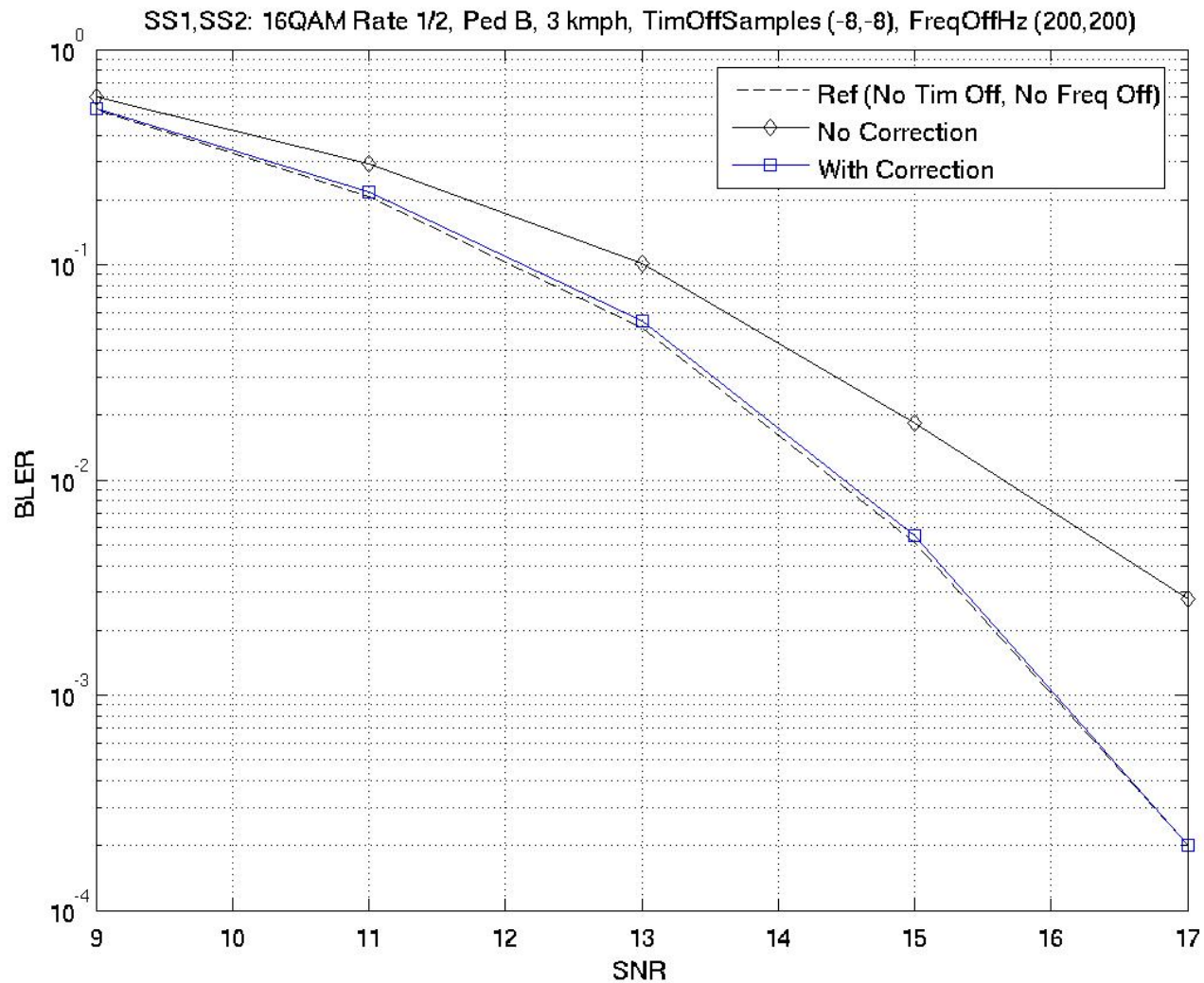


# SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph Tim Off. (Samples): (8,-8), Freq Off. (Hz): (200,200)

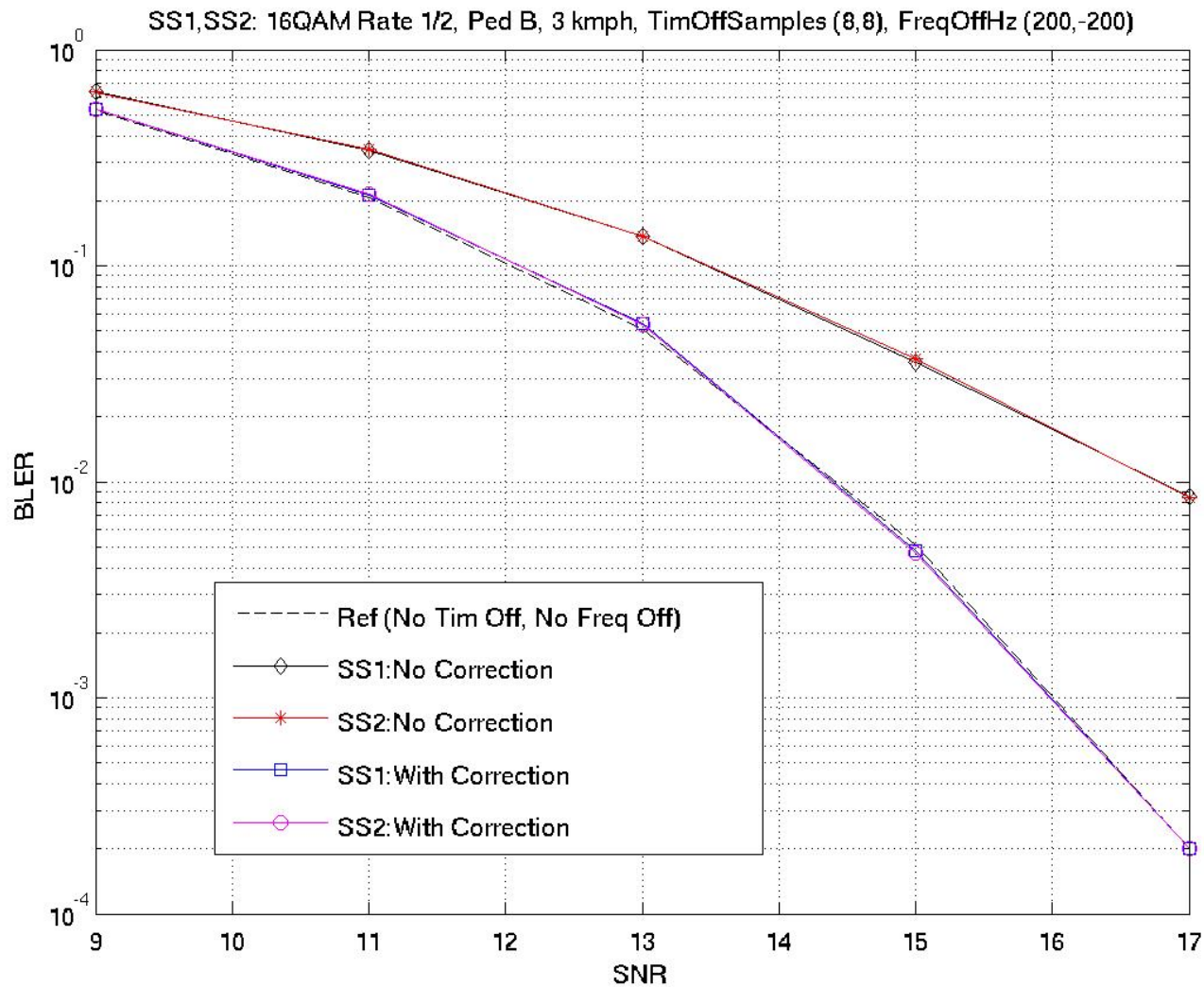


# SS #1, SS #2: 16QAM 1/2, Ped B, 3 kmph

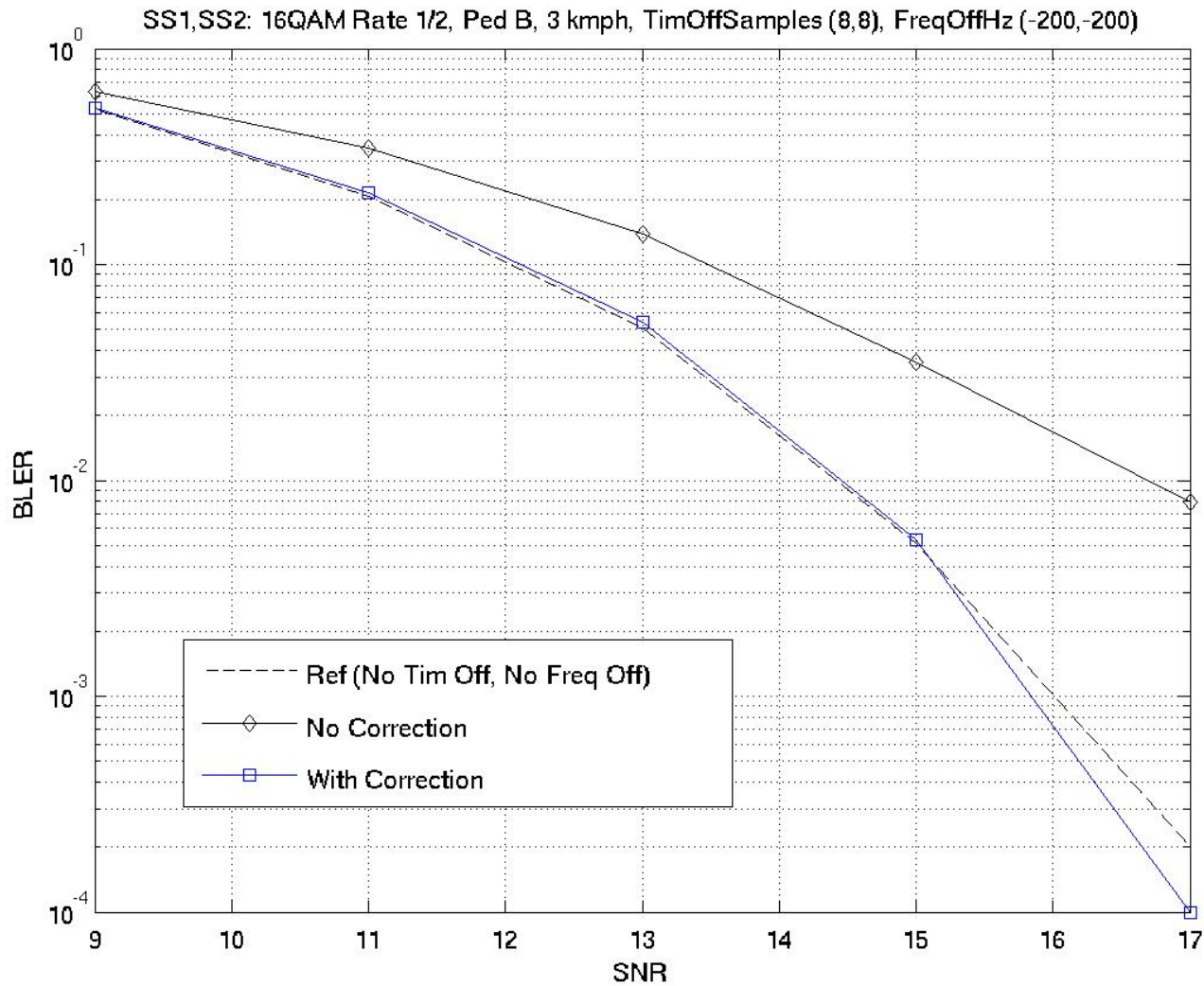
## Tim Off. (Samples): (-8,-8), Freq Off. (Hz): (200,200)



# 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)

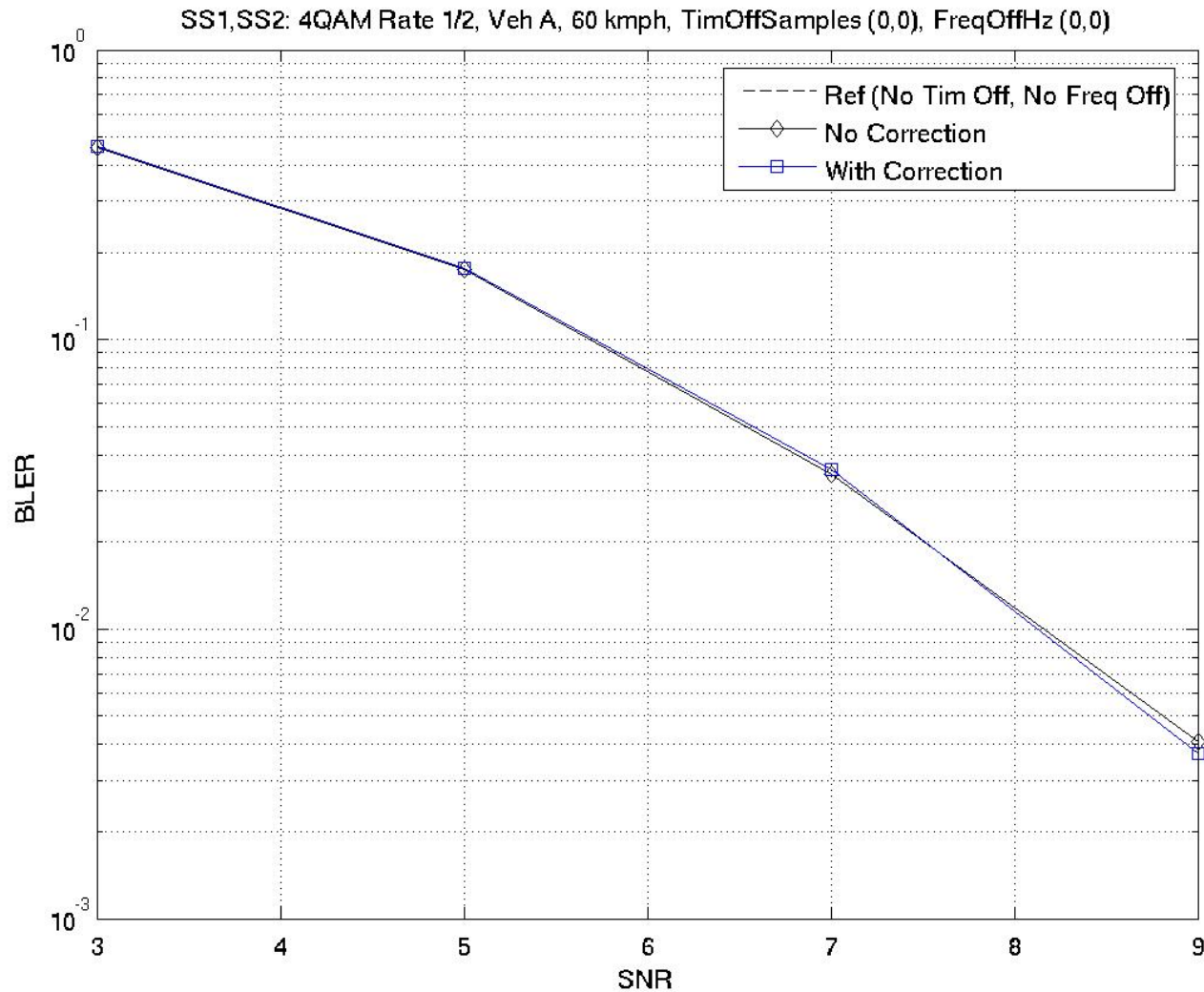


## Simulation Scenario III

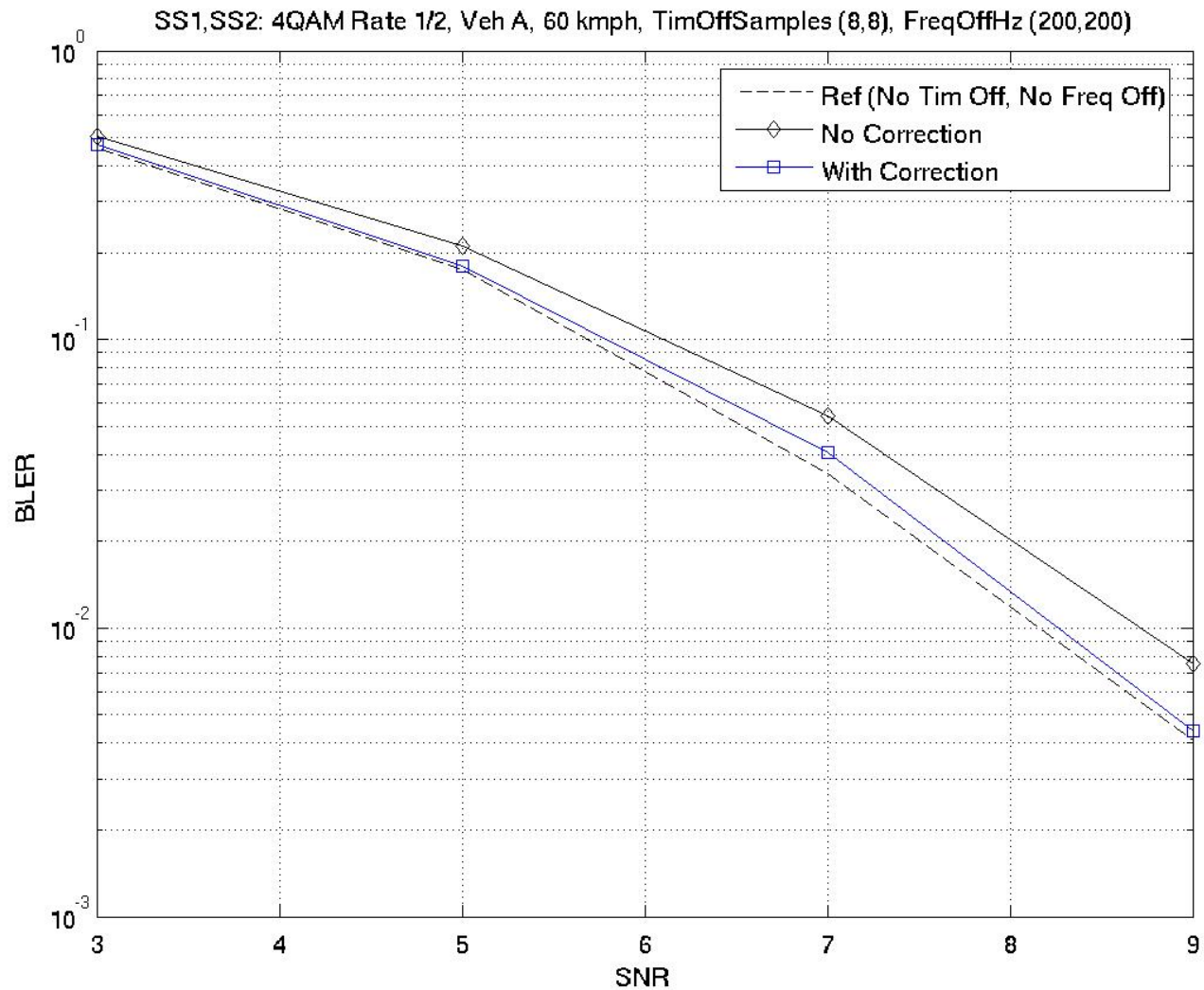
- SS#1, SS#2: 4QAM Rate  $\frac{1}{2}$ , Veh A, 60 kmph.

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

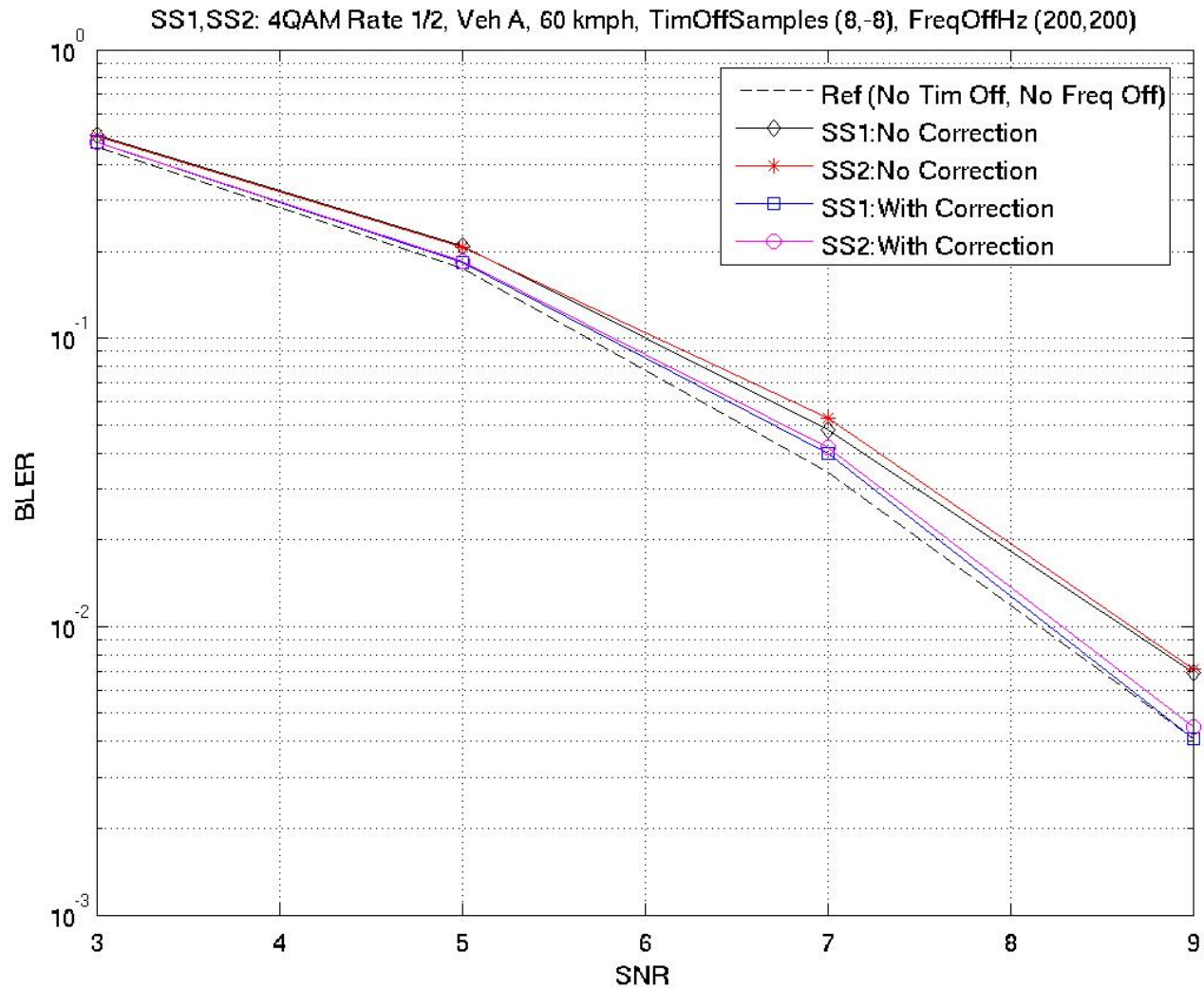
# SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph Tim Off. (Samples): (0,0), Freq Off. (Hz): (0,0)



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

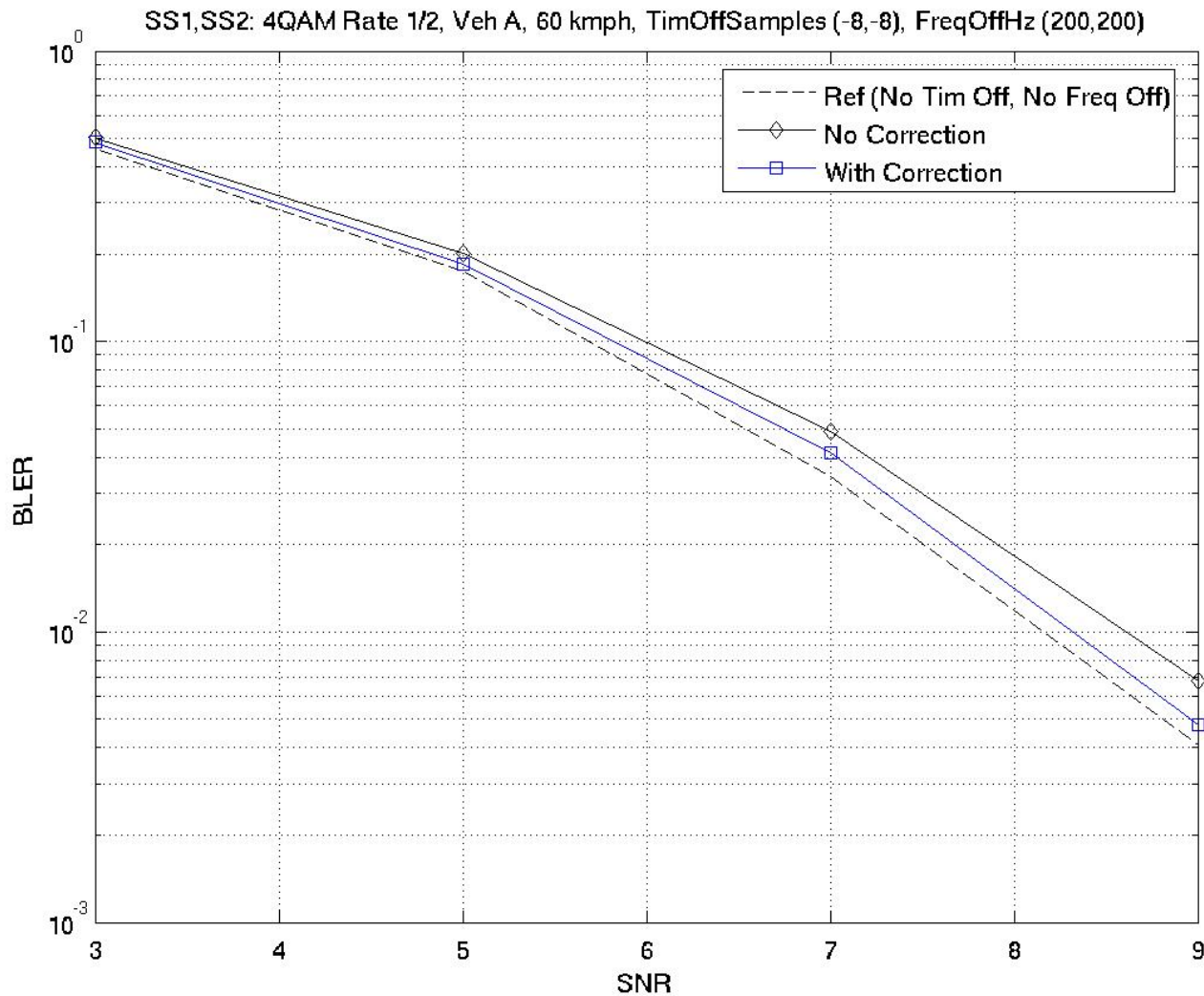


# SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph Tim Off. (Samples): (8,-8), Freq Off. (Hz): (200,200)

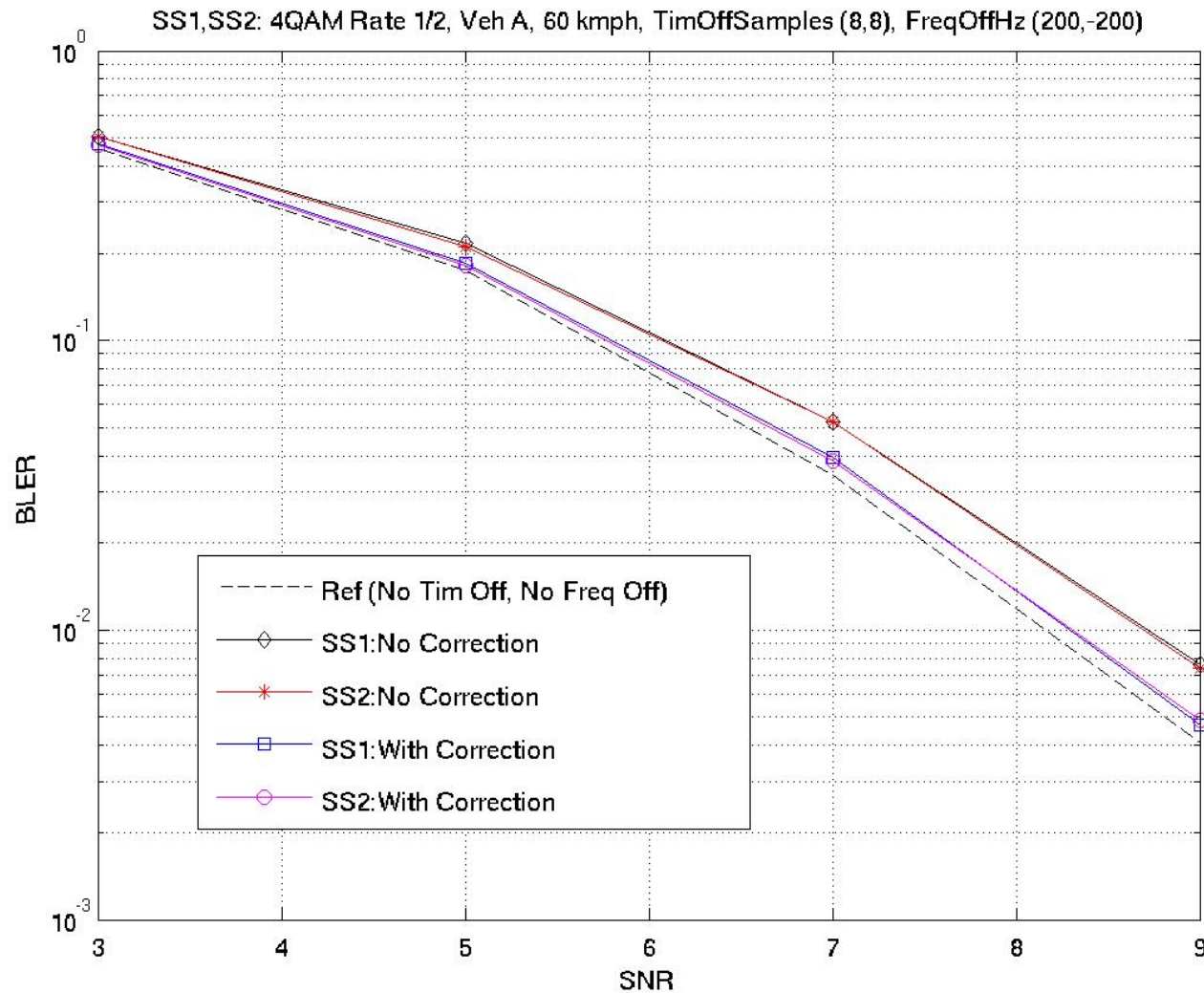




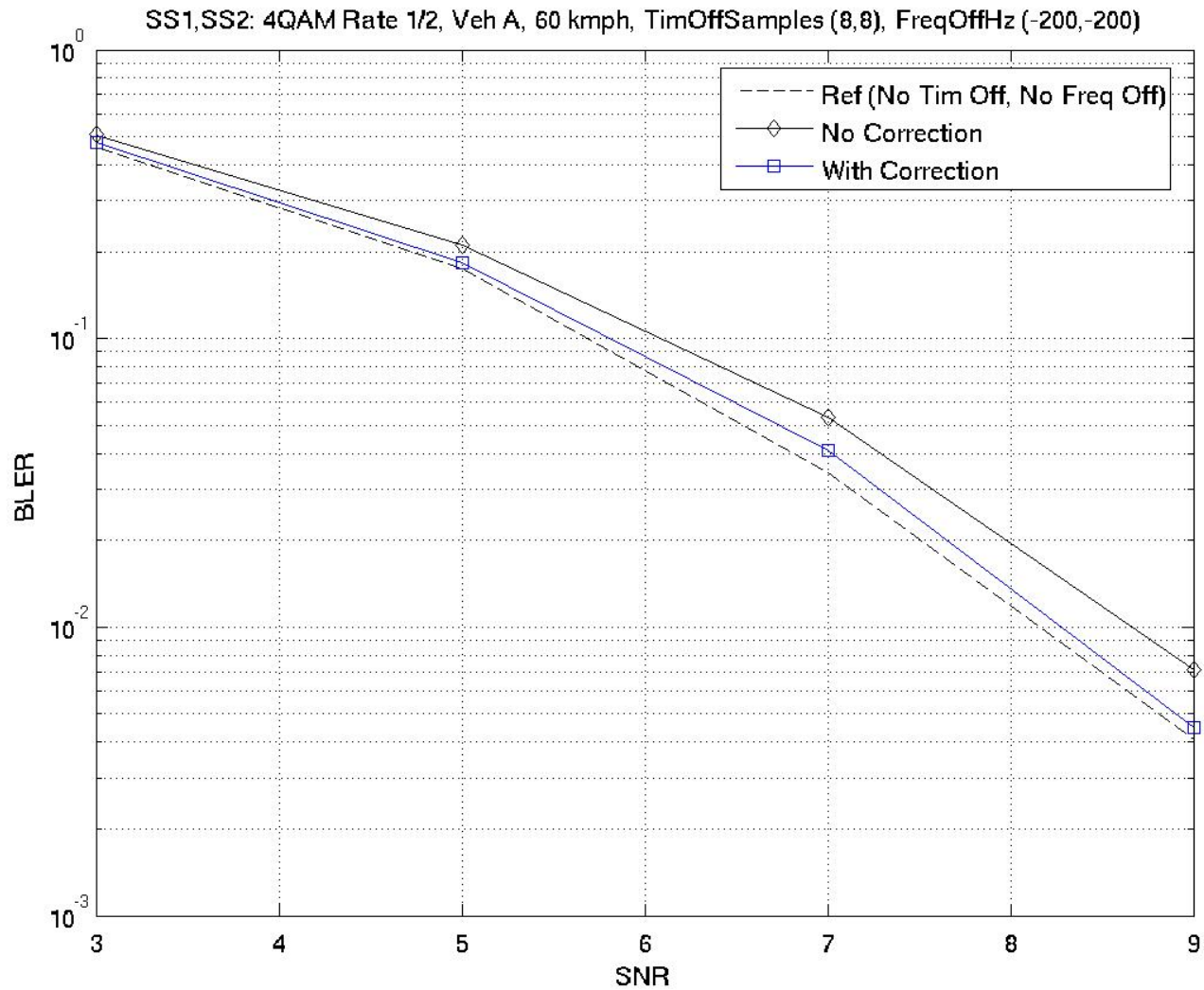
# SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph Tim Off. (Samples): (-8,-8), Freq Off. (Hz): (200,200)



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



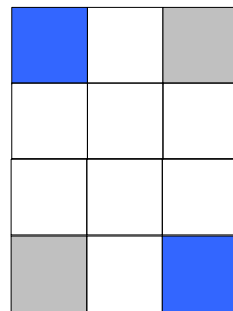
# SS #1, SS #2: 4QAM 1/2, Veh A, 60 kmph Tim Off. (Samples): (8,8), Freq Off. (Hz): (-200,-200)



# New Text

- Change Figure 275 in Rev2/D5 on page 1022 to the figure shown below. Add the following text to line 16: “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  $t = \text{mod}(s+k,2)$  “

tile structure 0



tile structure 1

