Comparison of Equalization Schemes for 6Gbps SAS Channels

Joe Caroselli, Amaresh V. Malipatil

High Speed Interface Systems Engineering

LSI Logic

Introduction

- Review of simulator and parameters
- Overview of channels
- Presentation of results

Simulator Review

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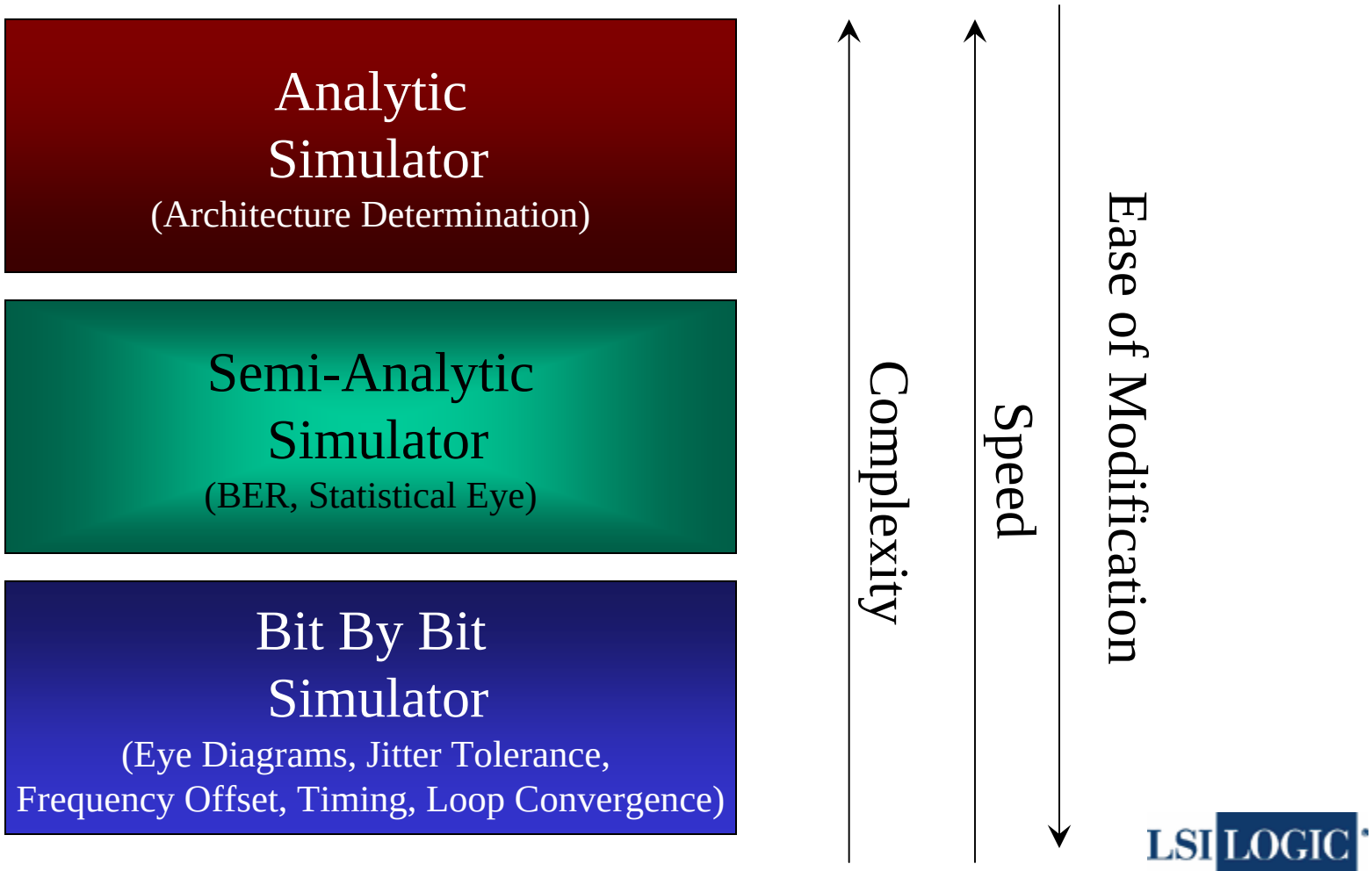
Three System Model Approach



Analytic Model

- Includes
  - Intersymbol Interference
  - Tx Jitter
  - Electronics (White) Noise
  - Crosstalk
- Does Not Include
  - Receiver Sensitivity
  - Duty Cycle Distortion
  - Other Sources of DJ

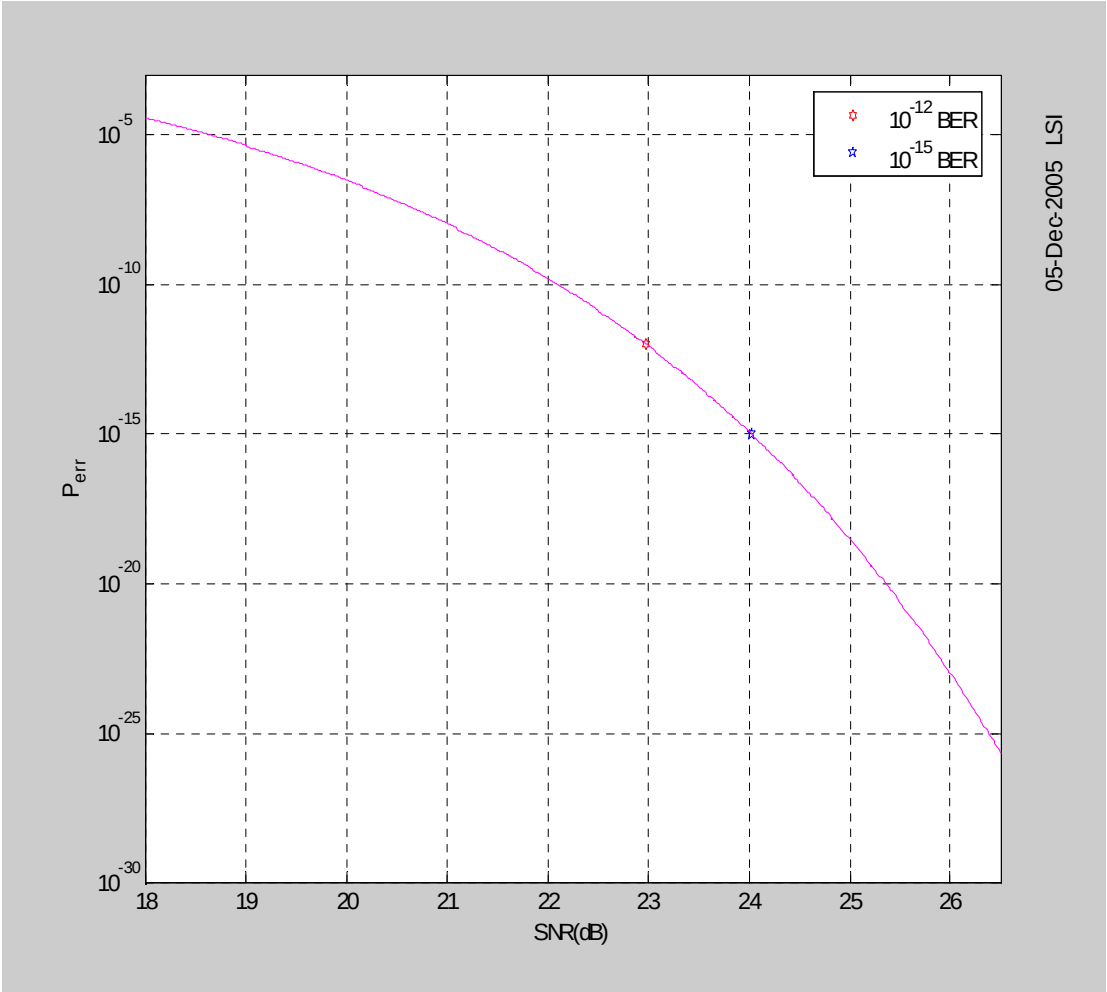
Required SNR

SNR Required at Slicer for 10^{-15} BER

$$SNR = \frac{d_{\min}^2}{\sigma^2}$$

$$\Pr_{err} \approx \frac{1}{2} erfc\left(\frac{\sqrt{SNR}}{2\sqrt{2}}\right)$$

- Approximately 24dB is required for an error rate of 10^{-15}



Overview of Simulations

- Equalization architectures with a linear FIR feedforward (FF) filter in the TX, and a decision feedback (FB) equalizer in the Rx are compared.
- The number of taps in the feedforward and feedback equalizers are varied.
- The effect of one near-end crosstalk aggressor is considered.
- A simple RC model with pole at 0.75*baud rate is used for the transmitter.
- Mellitz capacitor-like package model included on both transmitter and receiver.

Parameters Used

- Only DJ is from ISI
  - No DCD, PJ included
- 0.010UI σ RJ added
- Signal-To-Electronics Noise Ratio 45dB
- Crosstalk added as noted
- Ideal receiver sensitivity assumed

Description of Results

- SNR at optimal sampling point is shown. No measurement of horizontal eye opening is presented.
- x-axis shows number of DFE taps used
- Each line represents a different number of feed-forward (FF) equalizer taps used in the TX
- Crosstalk is assumed to occur at the same frequency as the signal. The worst case crosstalk phase at the ideal sampling point is selected.
- All tap values are ideal.

TCTF Backplanes

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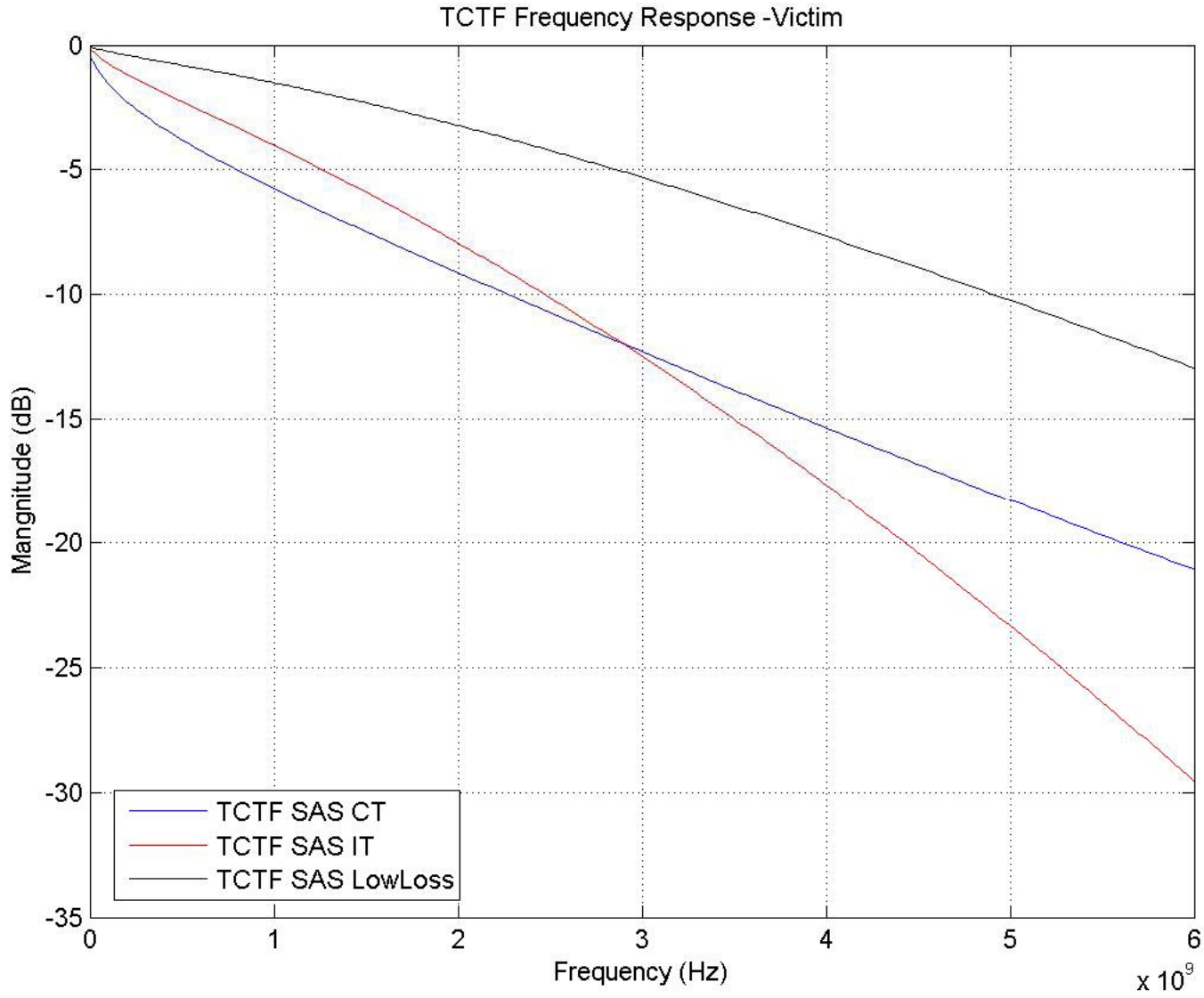
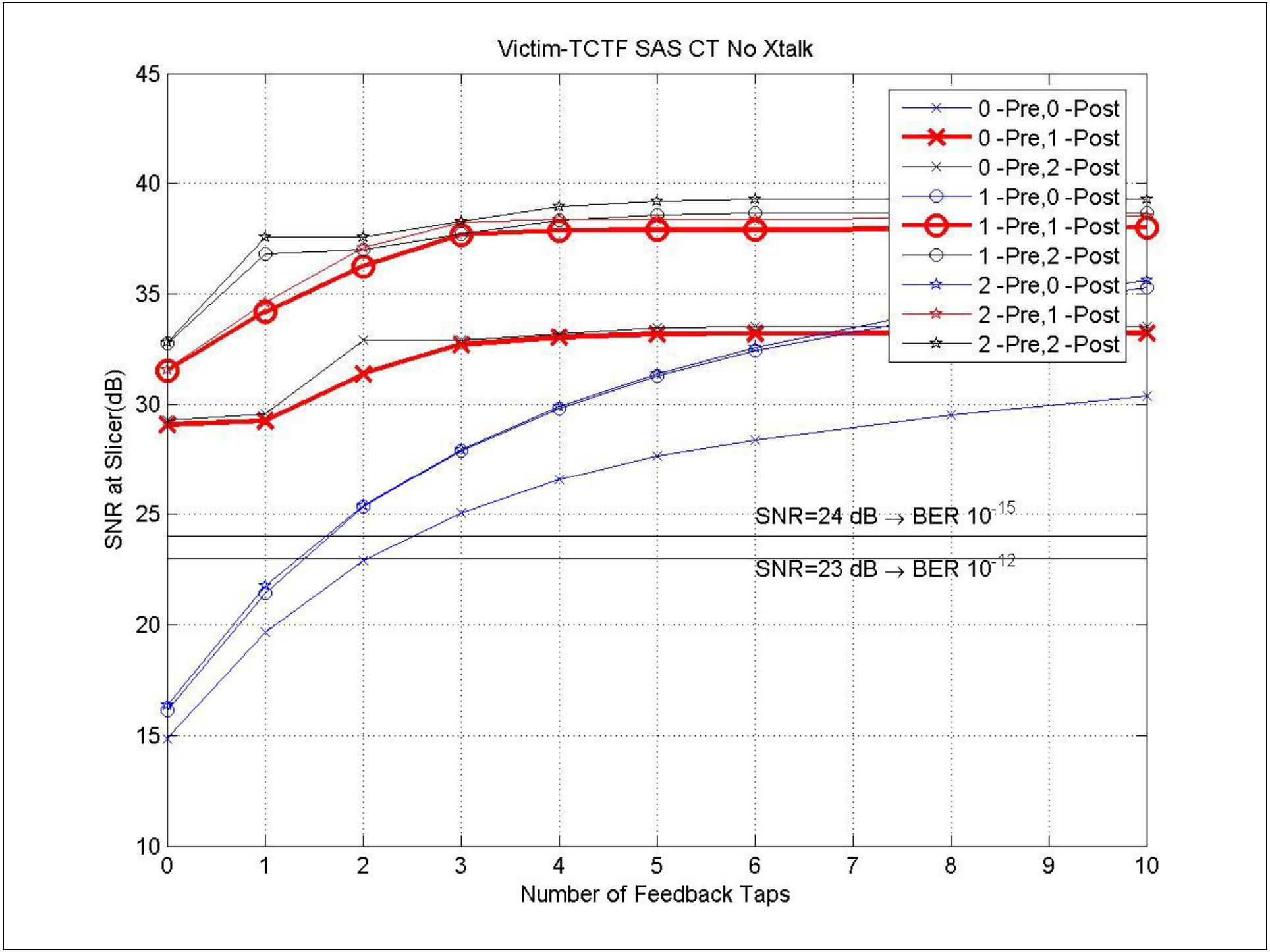

TCTF Frequency Response -Victim
Mangnitude (dB)
0
-5
-10
-15
-20
-25
-30
-35
0
1
2
3
4
5
6
Frequency (Hz)
x 10^9
TCTF SAS CT
TCTF SAS IT
TCTF SAS LowLoss


Victim-TCTF SAS CT No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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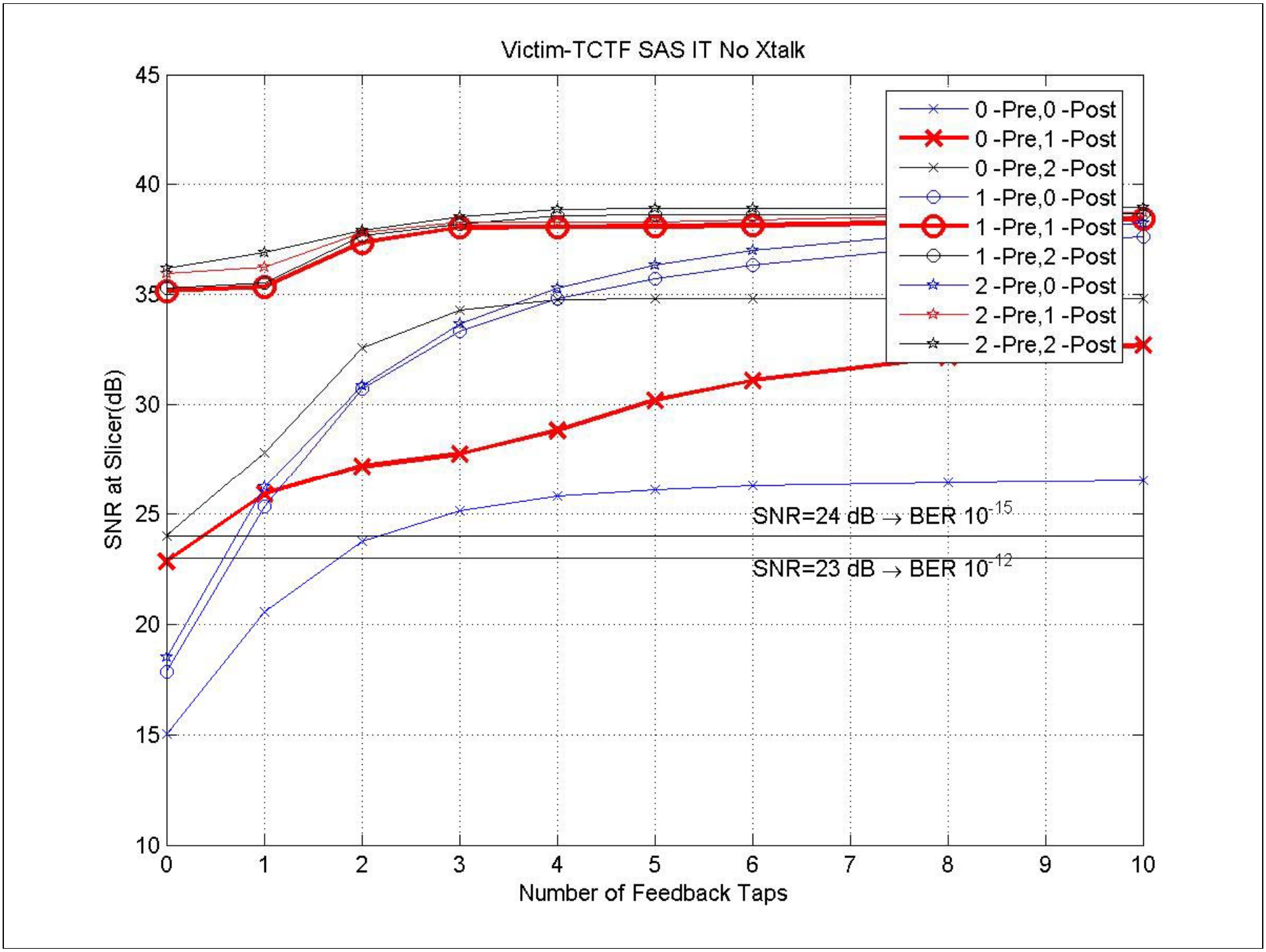
Victim-TCTF SAS IT No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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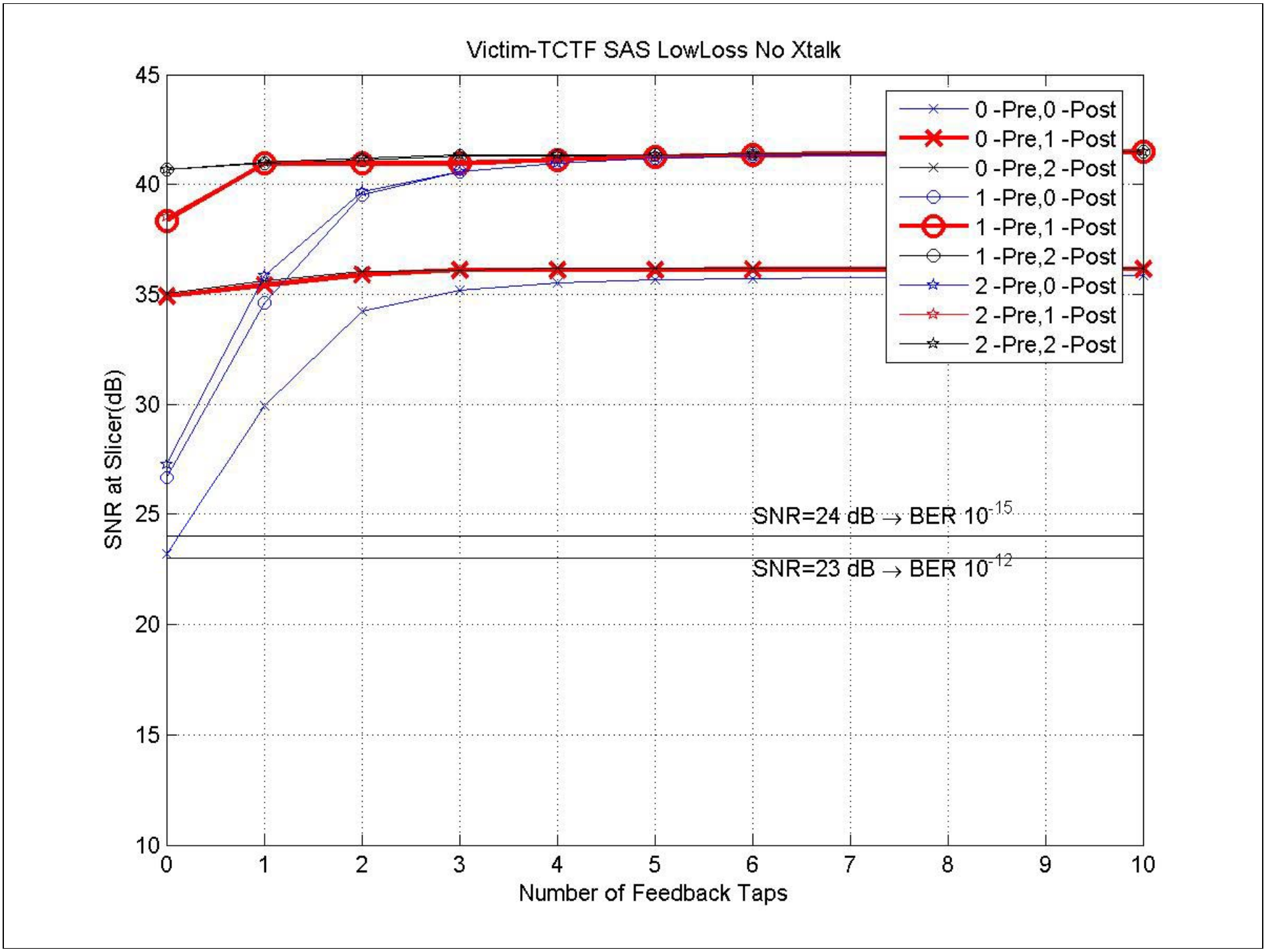
Victim-TCTF SAS LowLoss No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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Comparison to T10/05-428r0 Vertical Eye Opening

	6dB FFE No DFE	0dB FFE 5-tap DFE	# DFE taps/ dB de-emph No xtalk	# DFE taps/ dB de-emph HP15	# DFE taps/ dB de-emph HP16	# DFE taps/ dB de-emph HP17	# DFE taps/ dB de-emph HP18	# DFE taps/ dB de-emph HP19
HP01	0.10	0.20	0 / 7.0 dB	0 / 7.0 dB	0 / 7.0 dB	0 / 7.0 dB	0 / 7.0 dB	0 / 7.0 dB
HP02	0.10	0.22	0 / 6.4 dB	0 / 6.4 dB	0 / 6.4 dB	0 / 6.4 dB	0 / 6.4 dB	0 / 6.4 dB
HP03	0.12	0.25	0 / 6.6 dB	0 / 6.6 dB	0 / 6.6 dB	0 / 6.6 dB	0 / 6.6 dB	0 / 6.6 dB
HP04	0.13	0.25	0 / 5.4 dB	0 / 5.4 dB	0 / 5.4 dB	0 / 5.4 dB	0 / 5.4 dB	0 / 5.4 dB
HP05	0.11	0.22	0 / 6.5 dB	0 / 6.5 dB	0 / 6.5 dB	0 / 6.5 dB	0 / 6.5 dB	0 / 6.5 dB
HP06	0.09	0.18	0 / 8.3 dB	0 / 8.3 dB	0 / 8.3 dB	0 / 8.3 dB	0 / 8.3 dB	0 / 8.3 dB
HP07	0.11	0.21	0 / 6.8 dB	0 / 6.8 dB	0 / 6.8 dB	0 / 6.8 dB	0 / 6.8 dB	0 / 6.8 dB
HP08	0.11	0.19	0 / 8.1 dB	0 / 8.1 dB	0 / 8.1 dB	0 / 8.1 dB	0 / 8.1 dB	0 / 8.1 dB
HP09	0.03	0.12	0 / 8.7 dB					
HP10	Closed	0.11	1 / 5.7 dB					
HP11	0.01	0.11	1 / 6.2 dB					
HP12	0.13	0.22		0 / 6.1 dB*				
HP13	0.12	0.24		0 / 4.1 dB**				
HP14	0.09	0.21	0 / 2.9 dB					

*** HP12 with HP20 or HP22 as aggressor.**
**** HP13 with HP21 or HP23 as aggressor.**

Conclusions

- Dell, Molex and TCTF require no DFE or 1-tap DFE
- HP Channels require more DFE compensation and the DFE requirements vary significantly depending on the victim and the aggressor. (See following detailed results)
- A reasonable compromise between chip area & power and the number of channels that can be supported is:
  - Reference TX: 1post-cursor FFE tap (plus possibly one pre-cursor FFE tap)
  - Reference RX: 1 (or possibly 2) DFE taps

Summary of Results

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HP Backplanes

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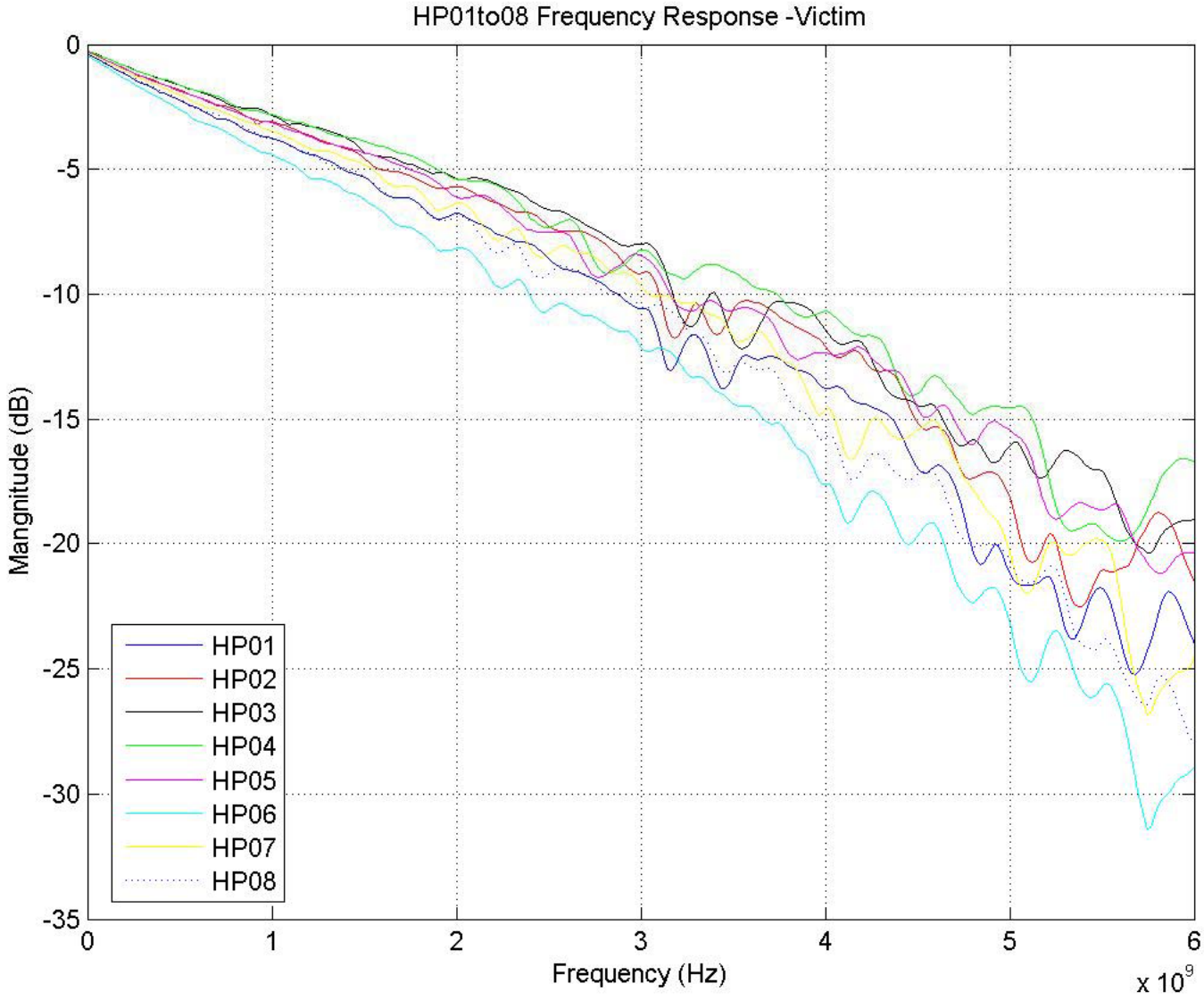
HP01to08 Frequency Response -Victim
Mangnitude (dB)
0
-5
-10
-15
-20
-25
-30
-35
0
1
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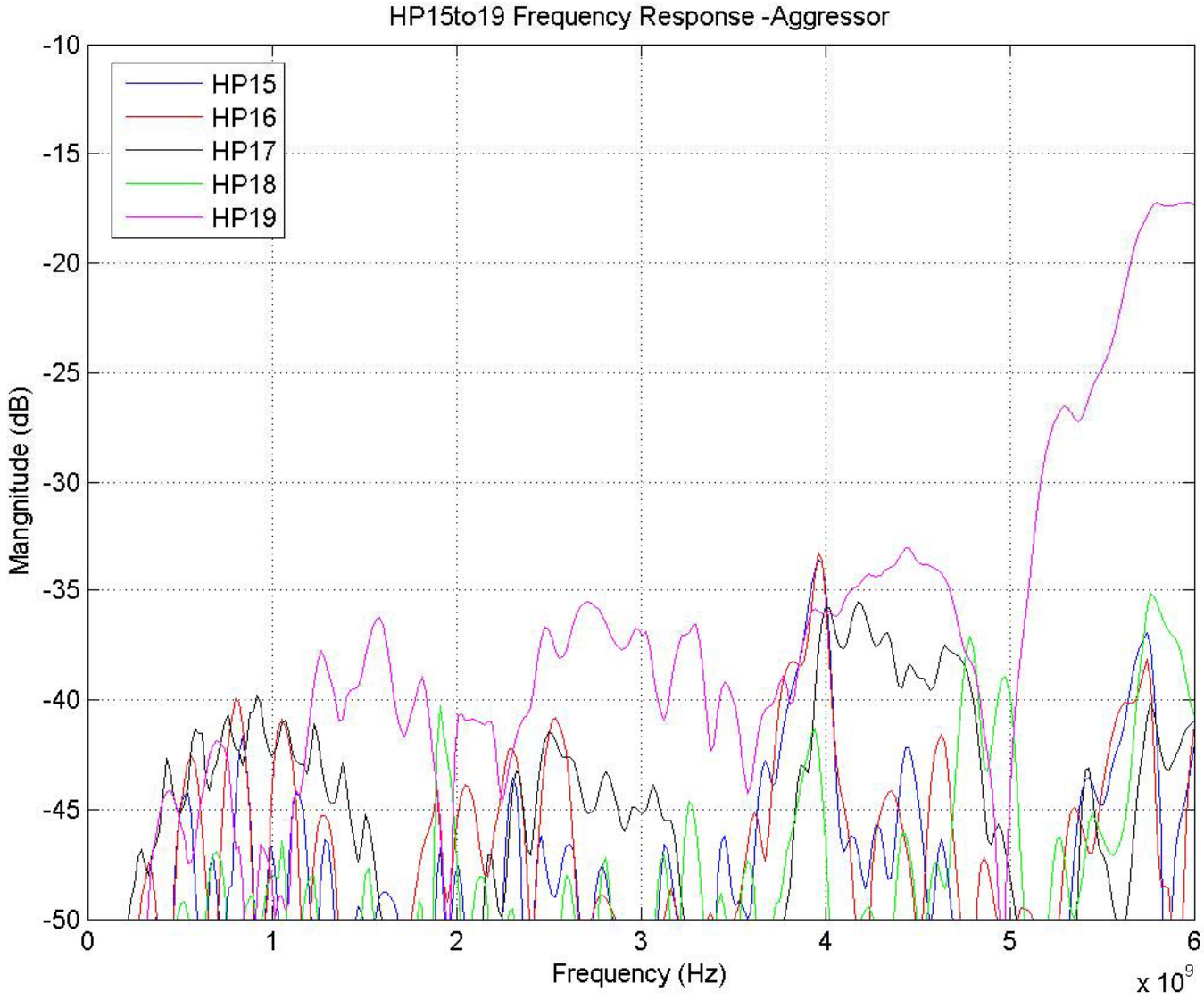
3
4
5
6
Frequency (Hz)
x 10^9
HP01
HP02
HP03
HP04
HP05
HP06
HP07
HP08


HP15to19 Frequency Response -Aggressor
HP15
HP16
HP17
HP18
HP19
Mangnitude (dB)
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
1
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3
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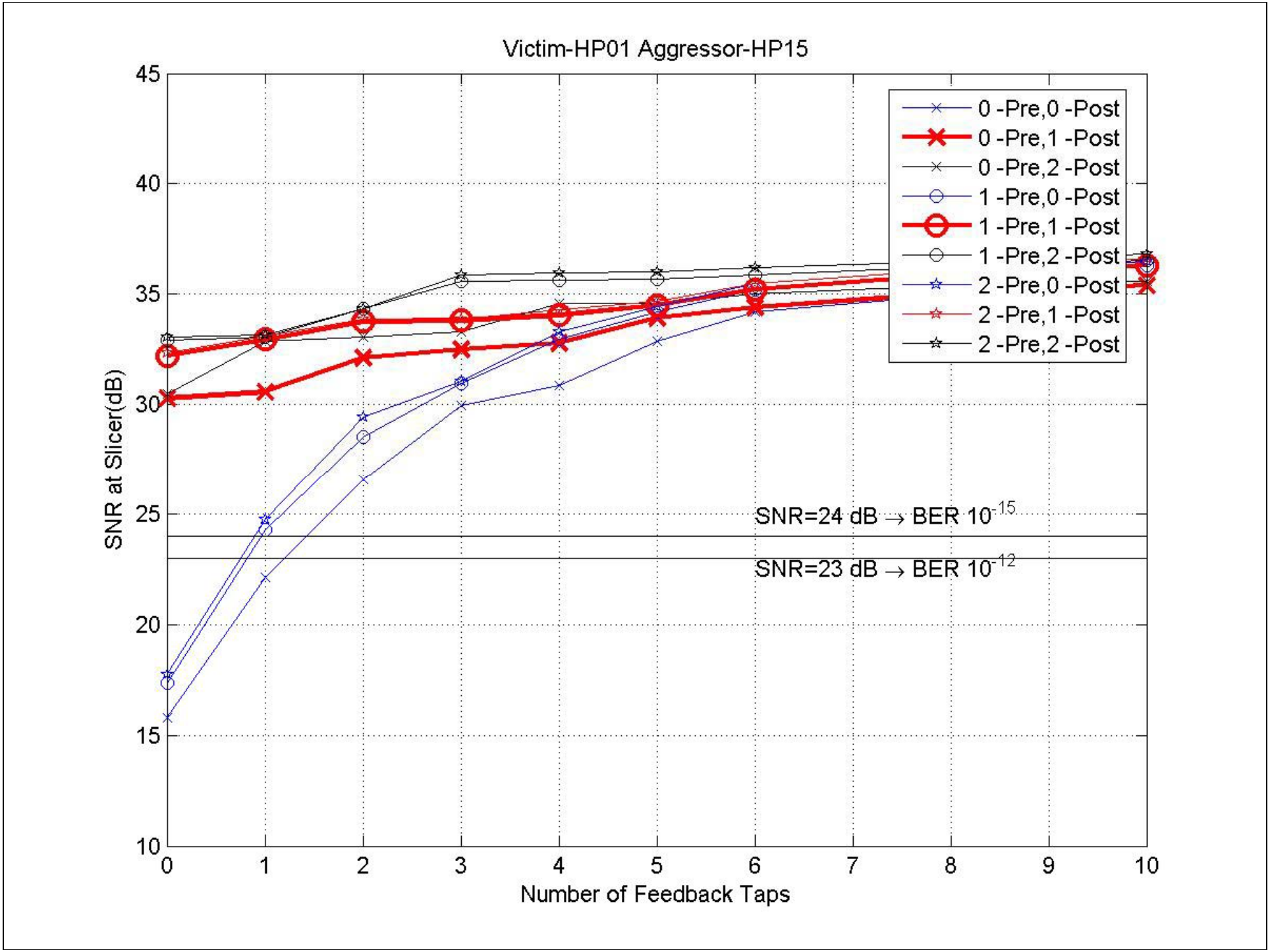
Frequency (Hz)
x 10^9


Victim-HP01 Aggressor-HP15
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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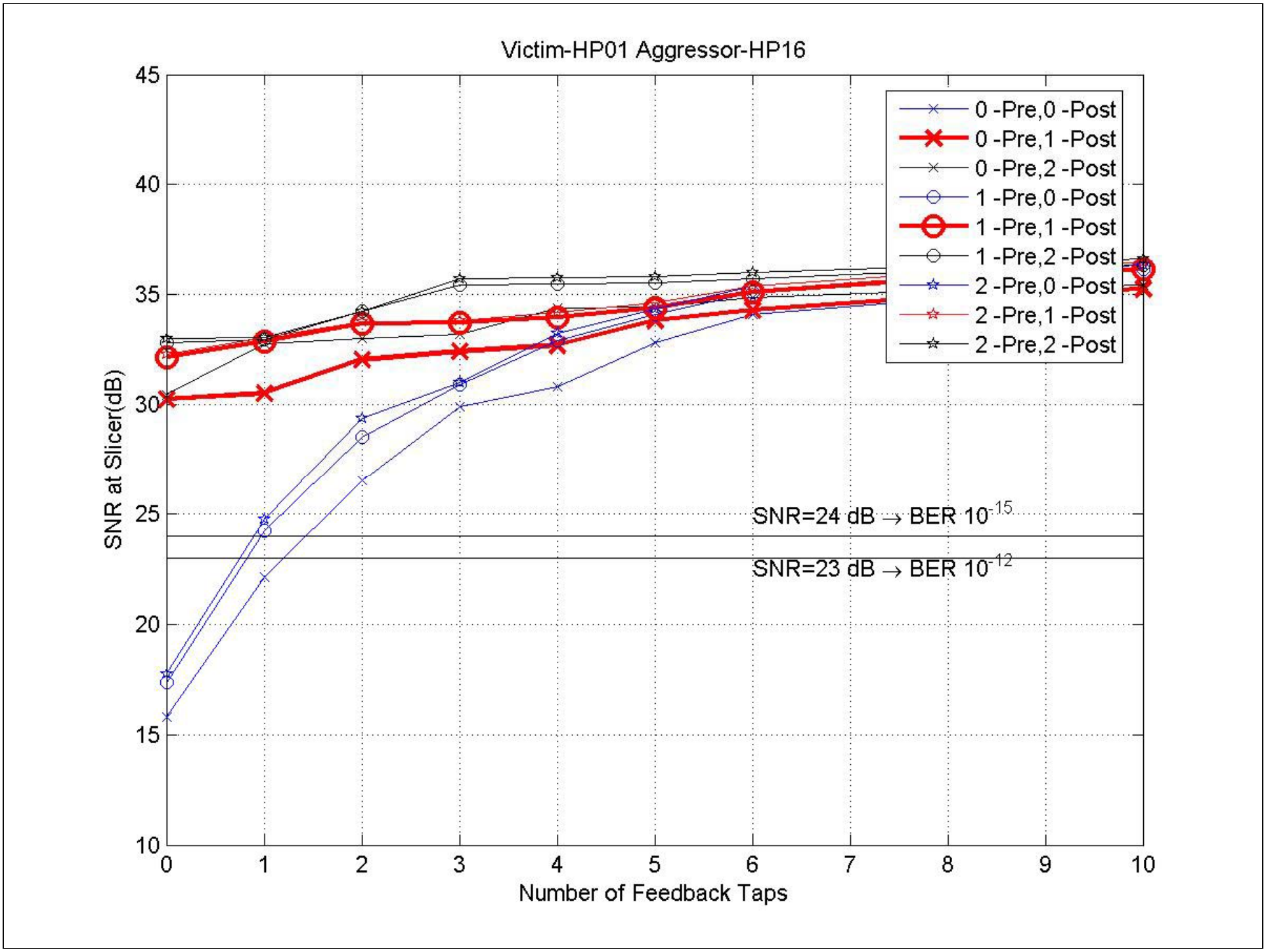
Victim-HP01 Aggressor-HP16
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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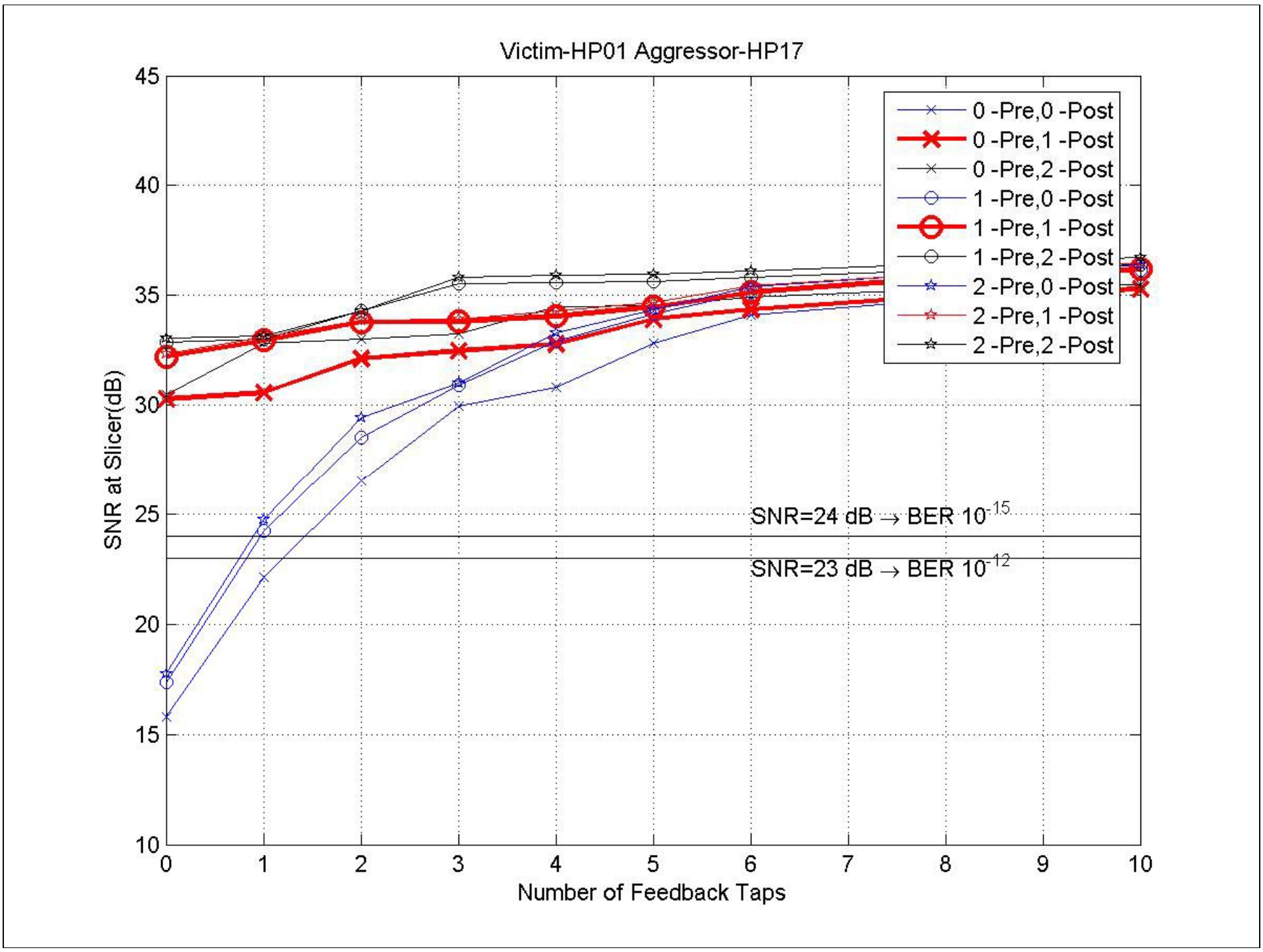
Victim-HP01 Aggressor-HP17
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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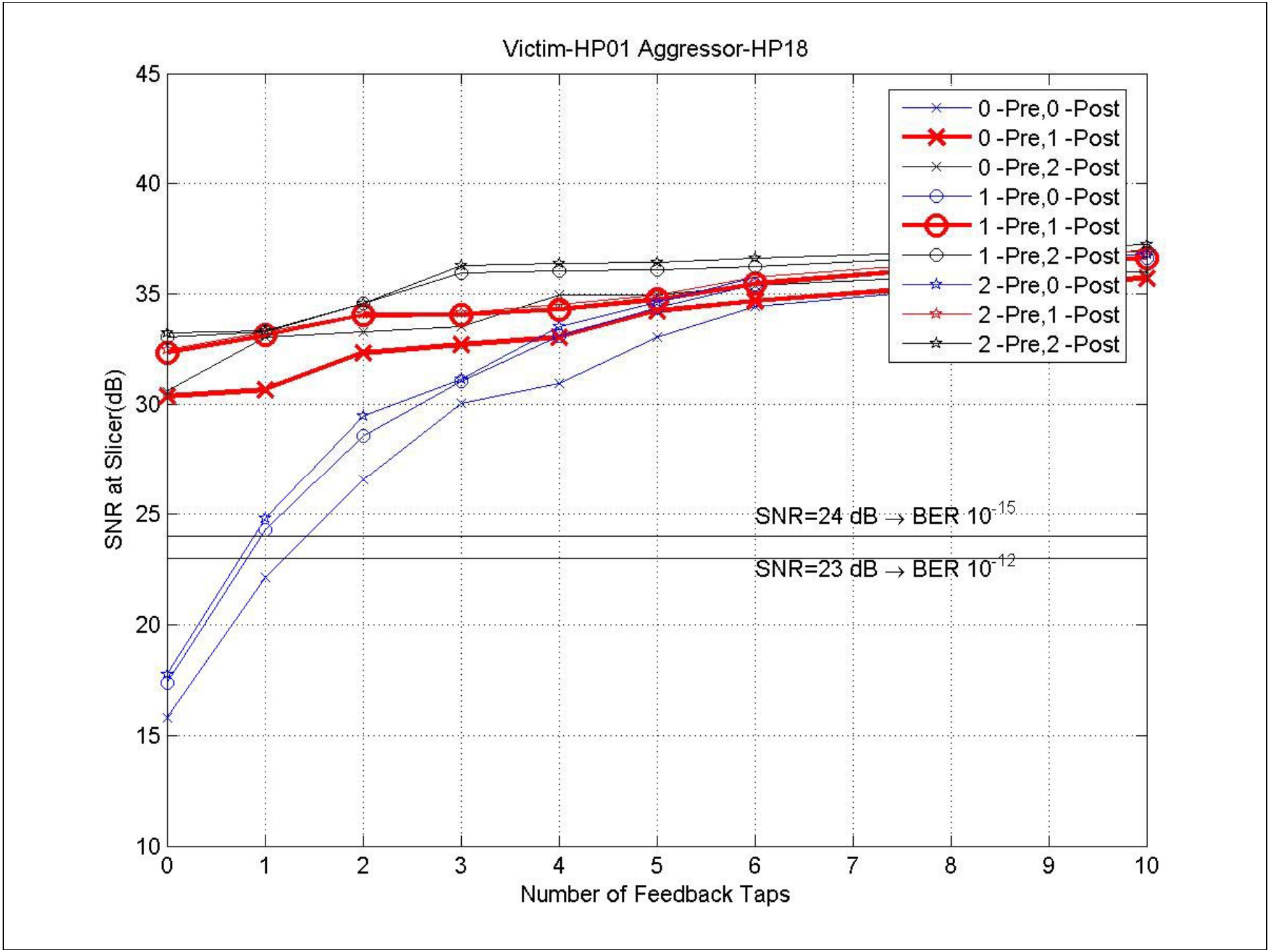
Victim-HP01 Aggressor-HP18
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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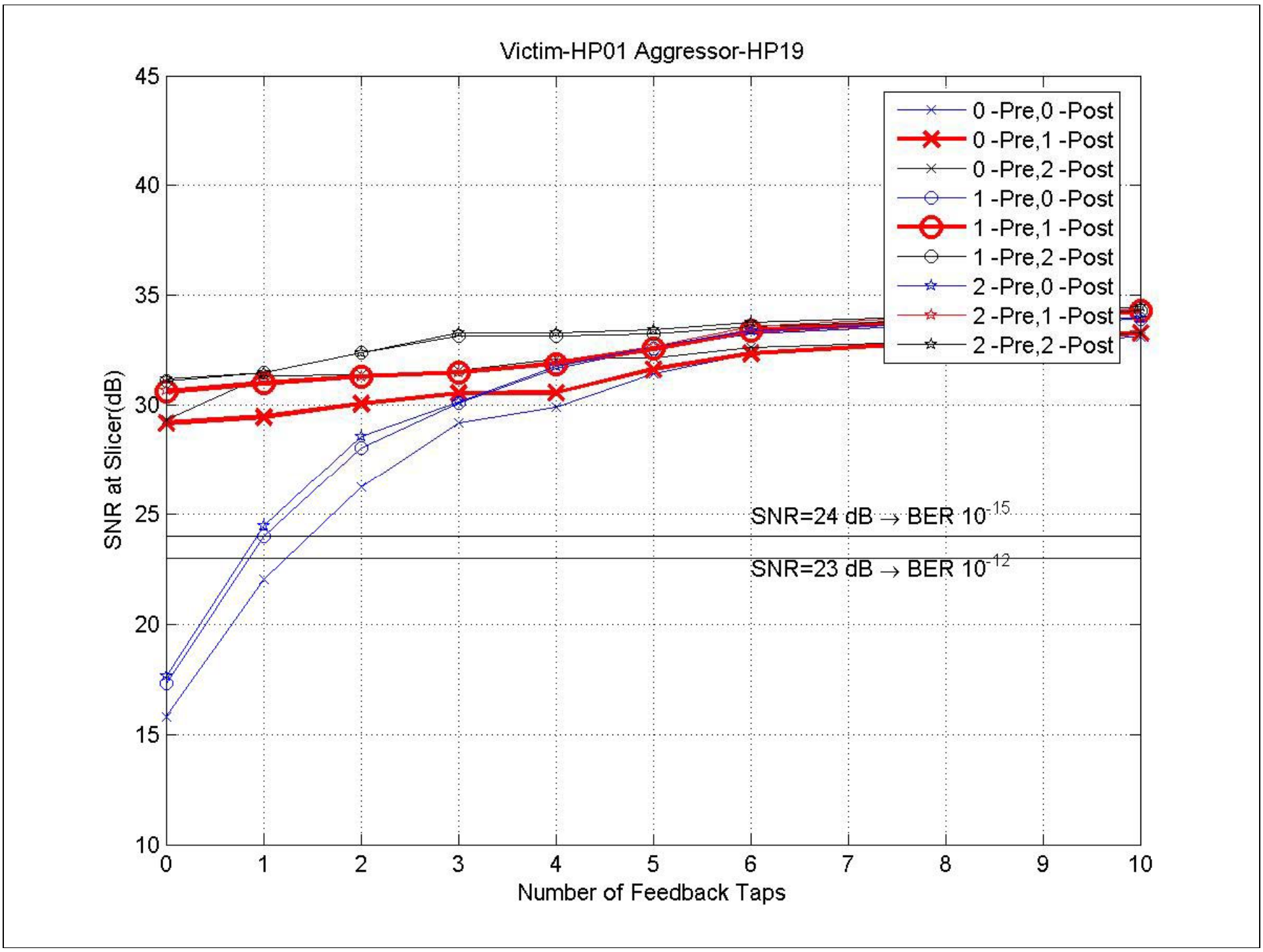
Victim-HP01 Aggressor-HP19
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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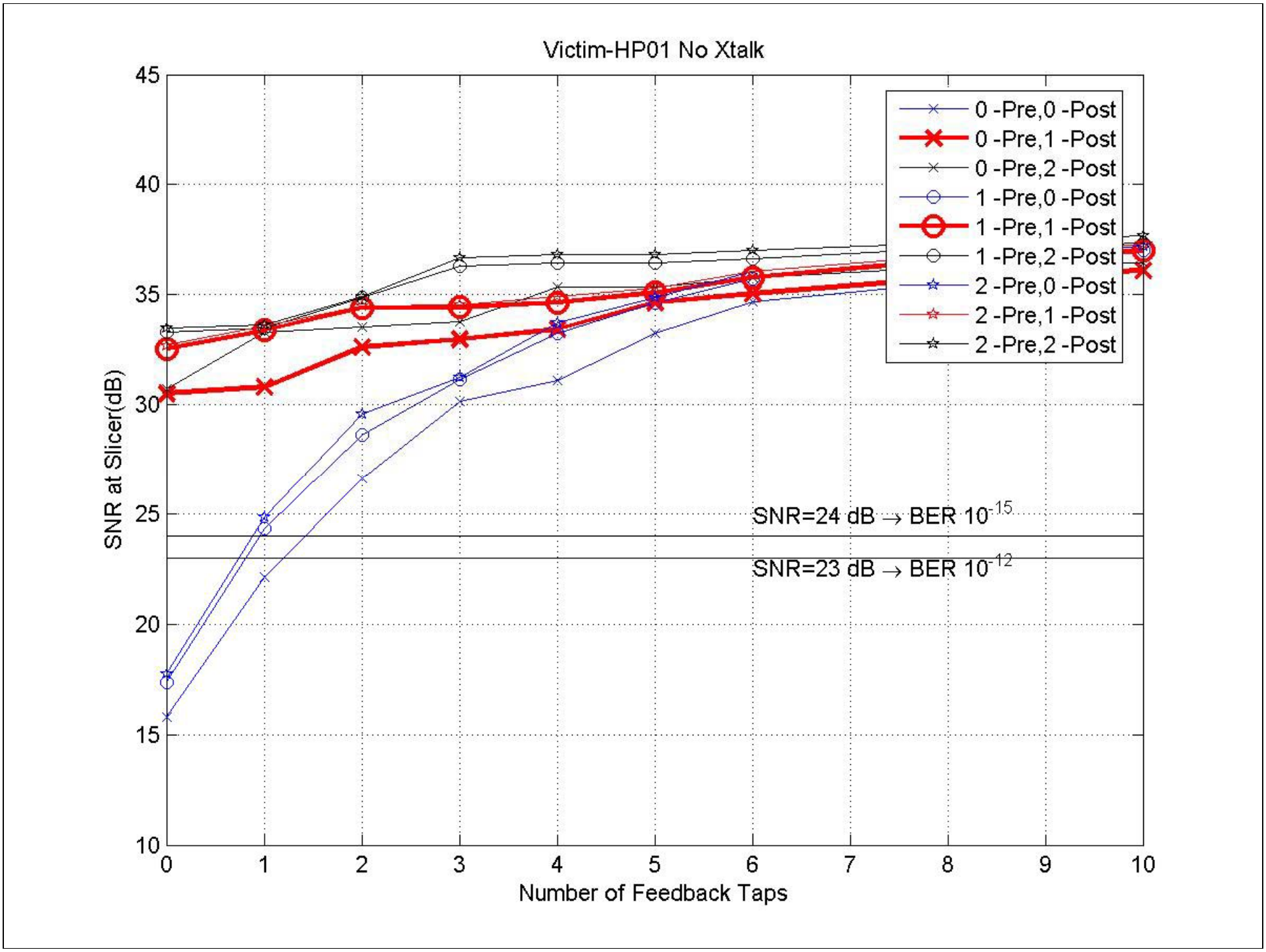
Victim-HP01 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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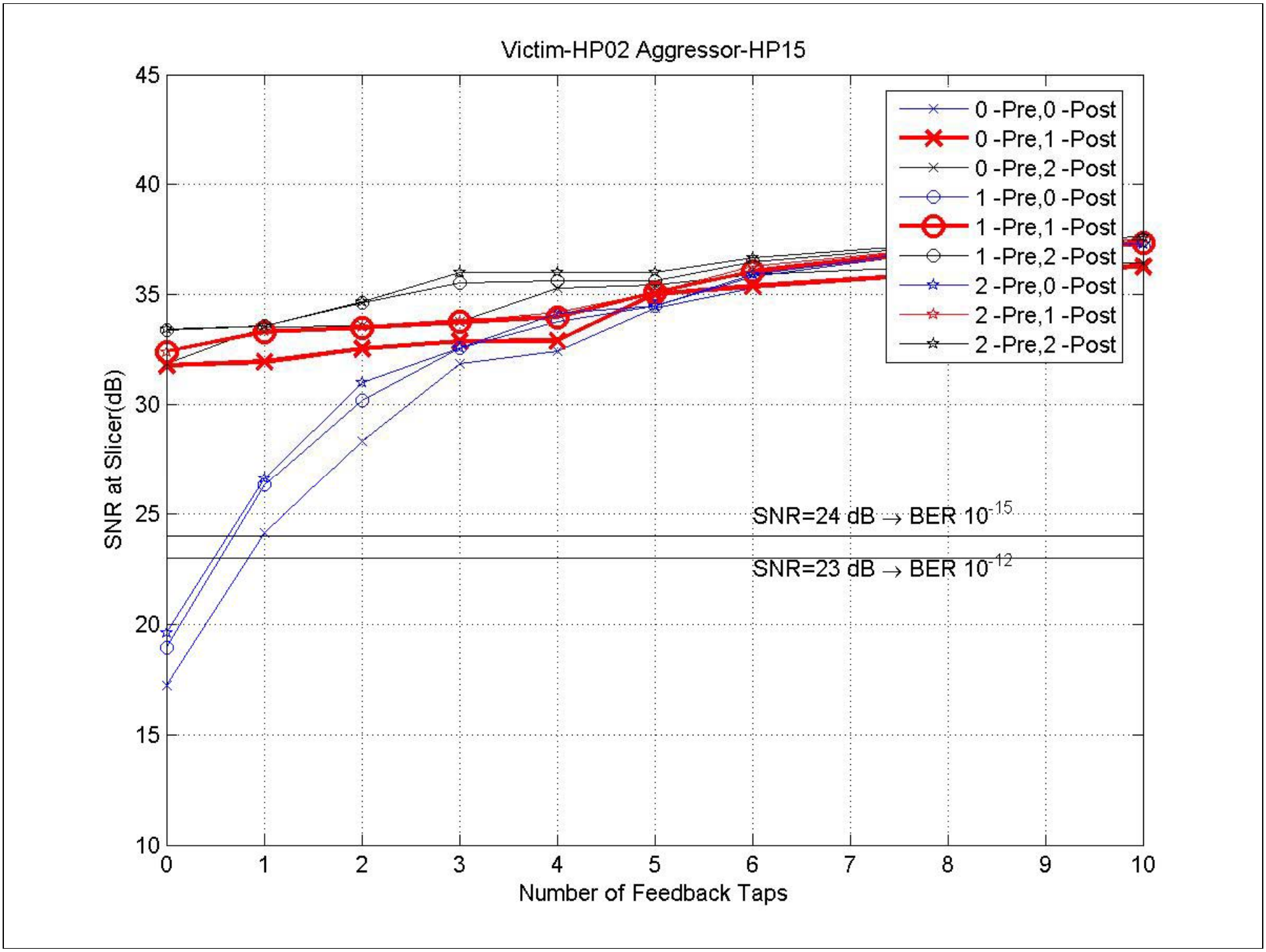
Victim-HP02 Aggressor-HP15
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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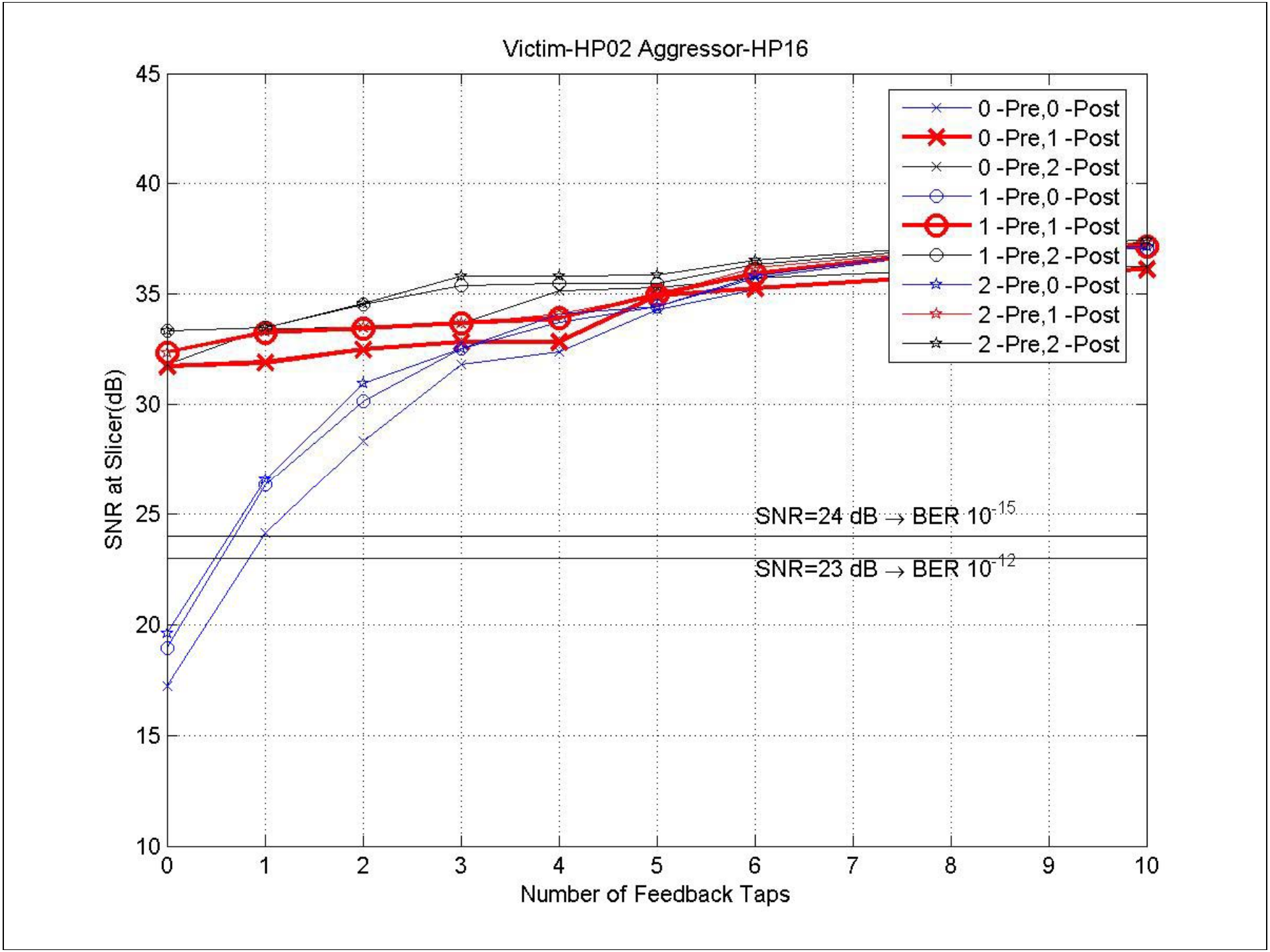
Victim-HP02 Aggressor-HP16
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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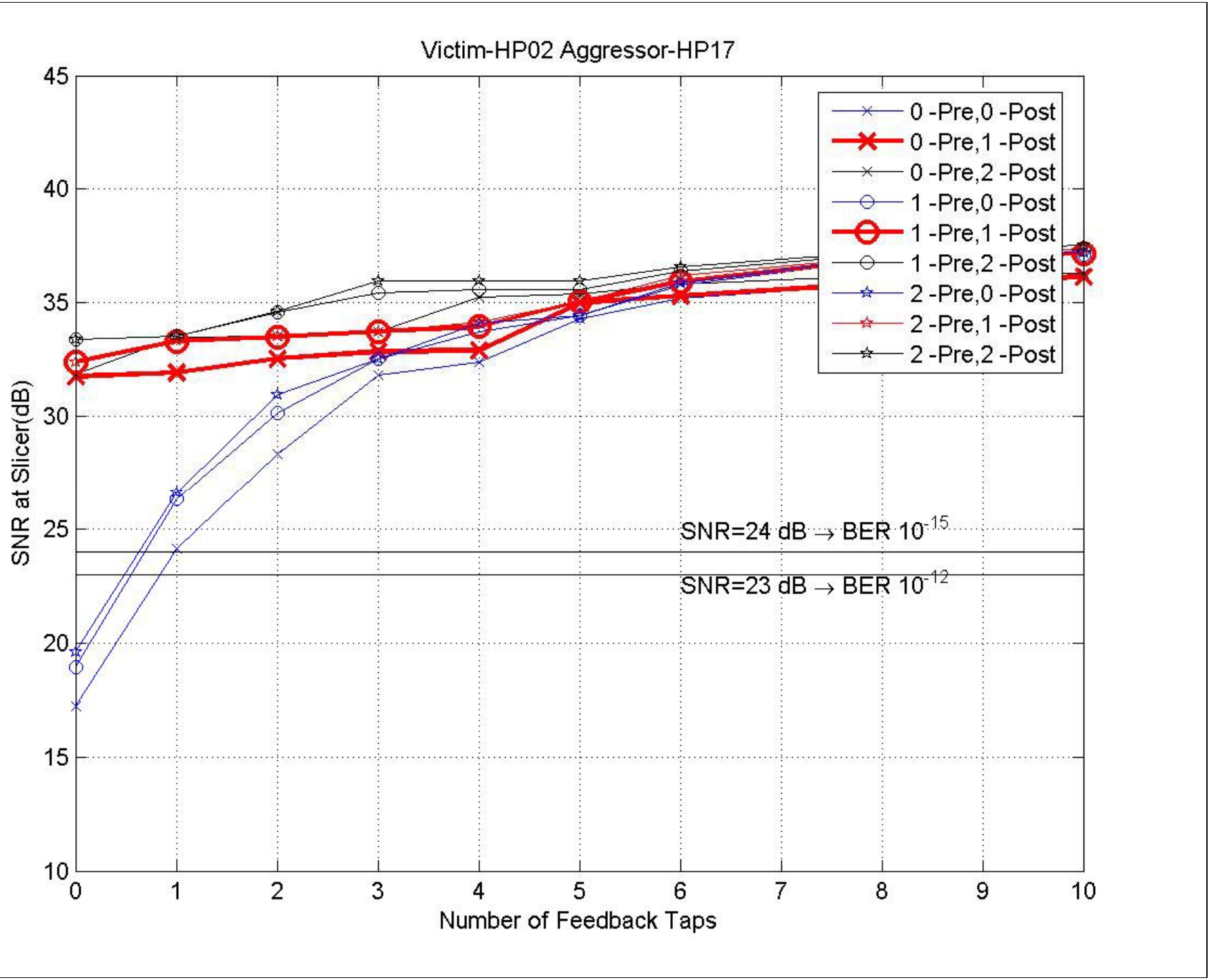
Victim-HP02 Aggressor-HP17
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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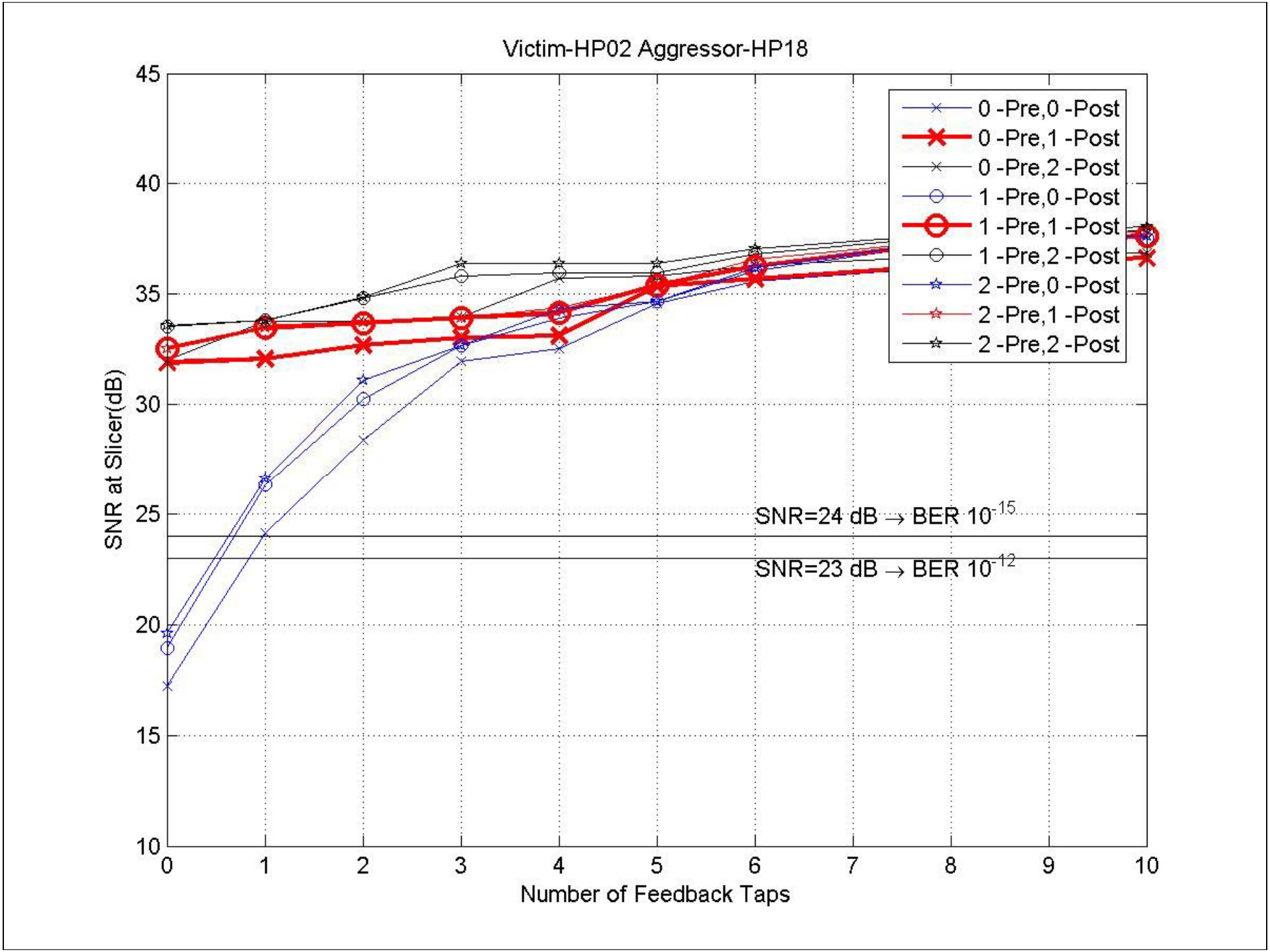
Victim-HP02 Aggressor-HP18
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
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SNR=24 dB → BER 10^-15
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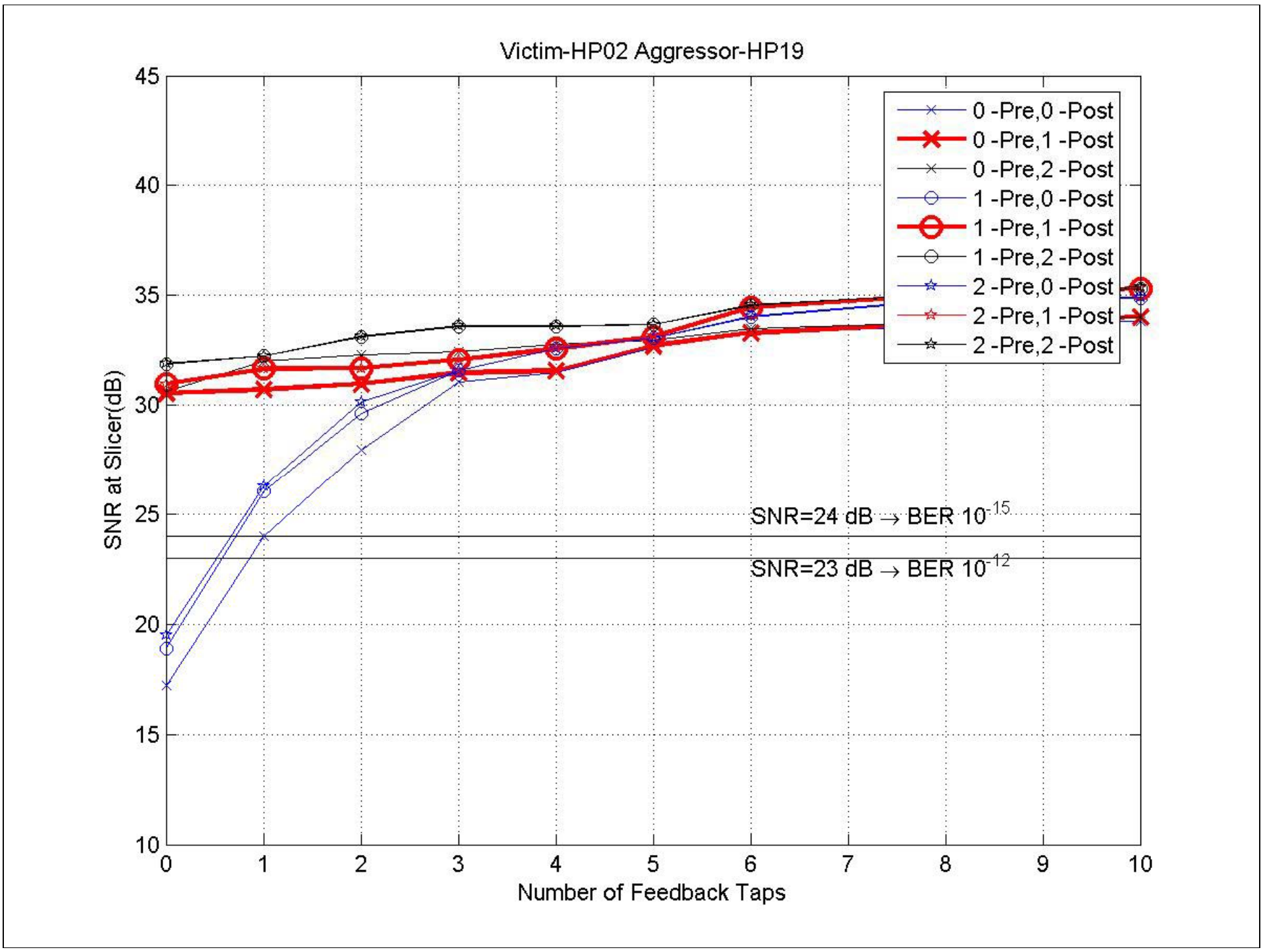
Victim-HP02 Aggressor-HP19
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
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SNR=24 dB → BER 10^-15
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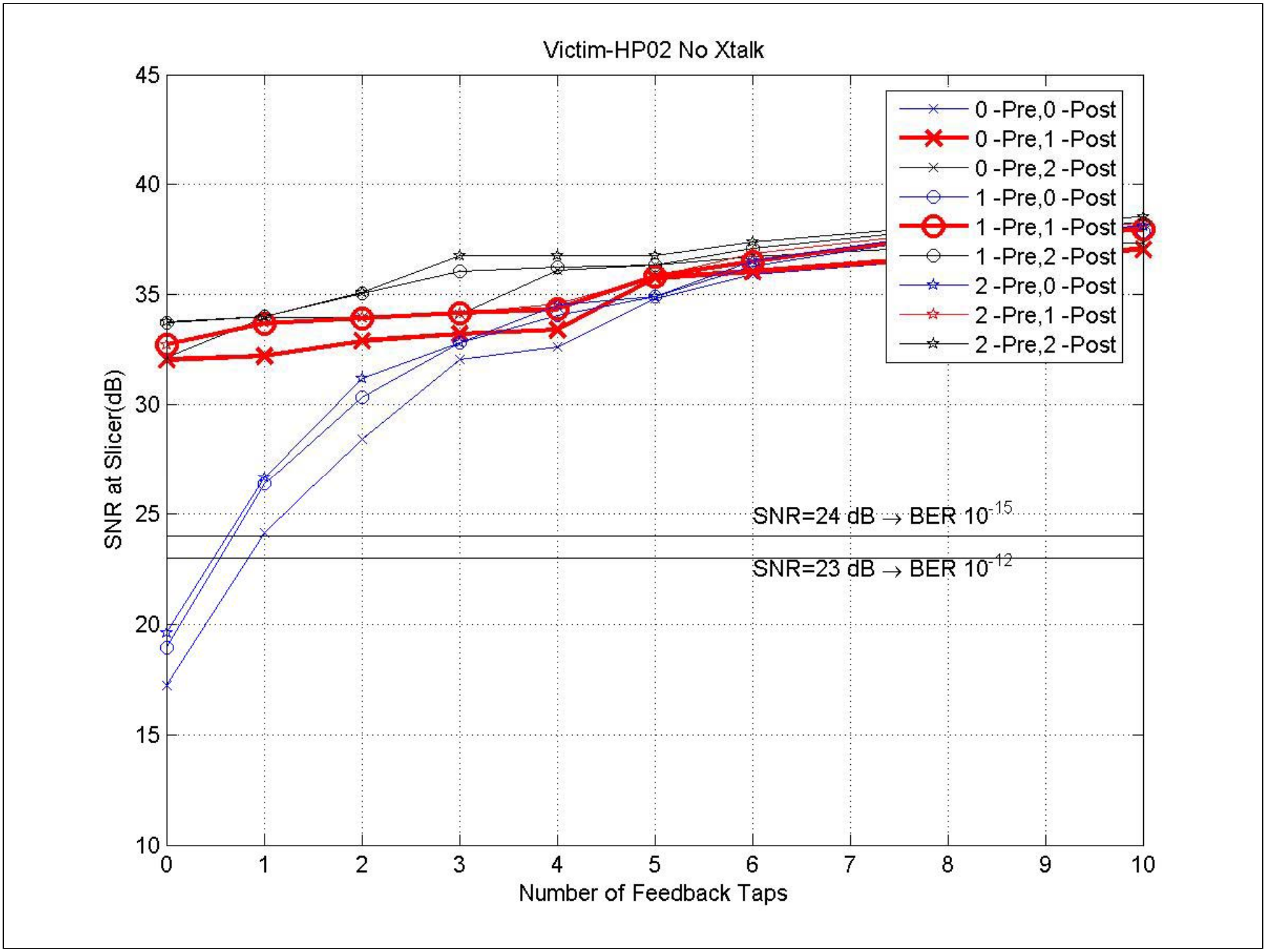
Victim-HP02 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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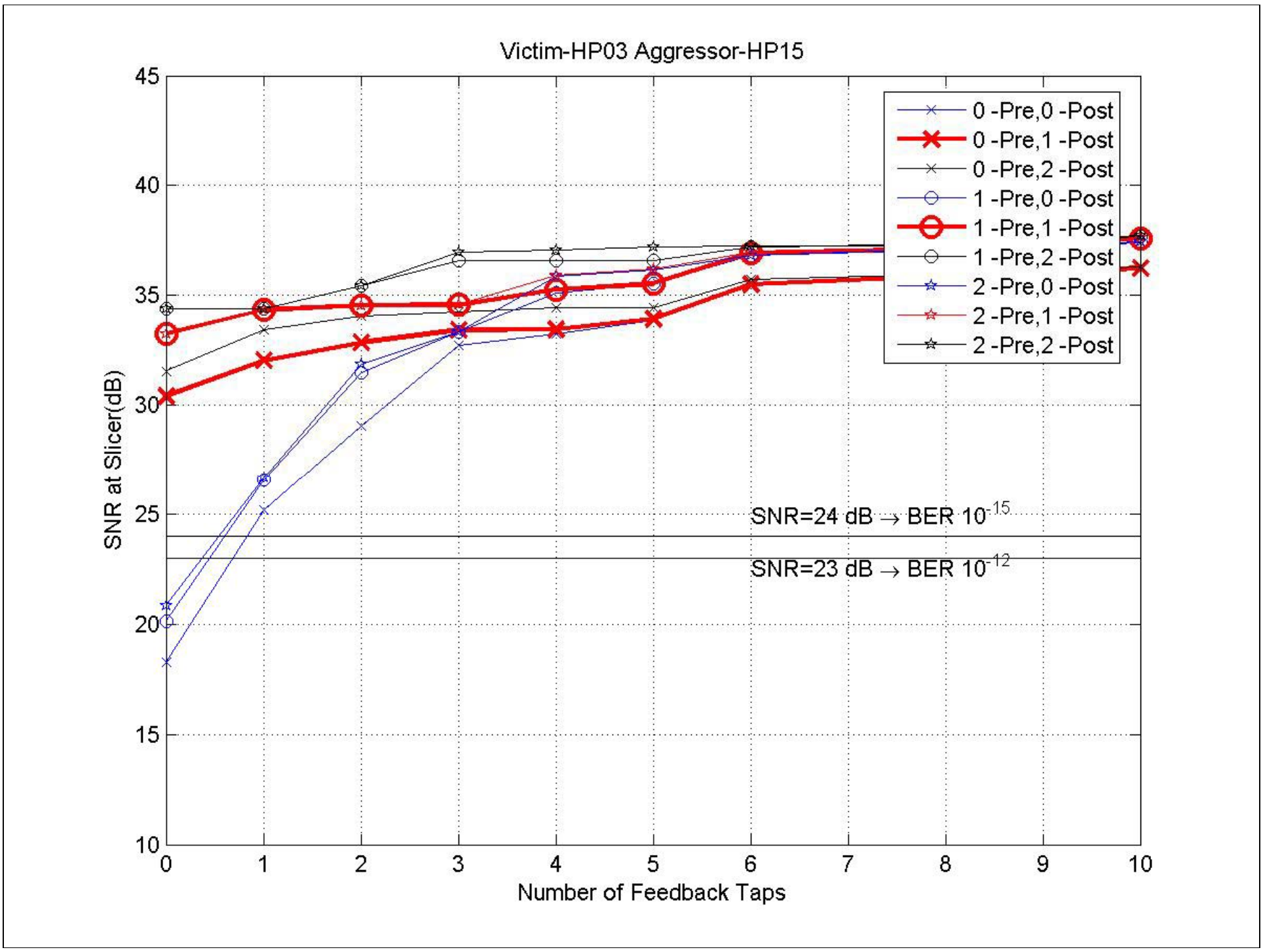
Victim-HP03 Aggressor-HP15
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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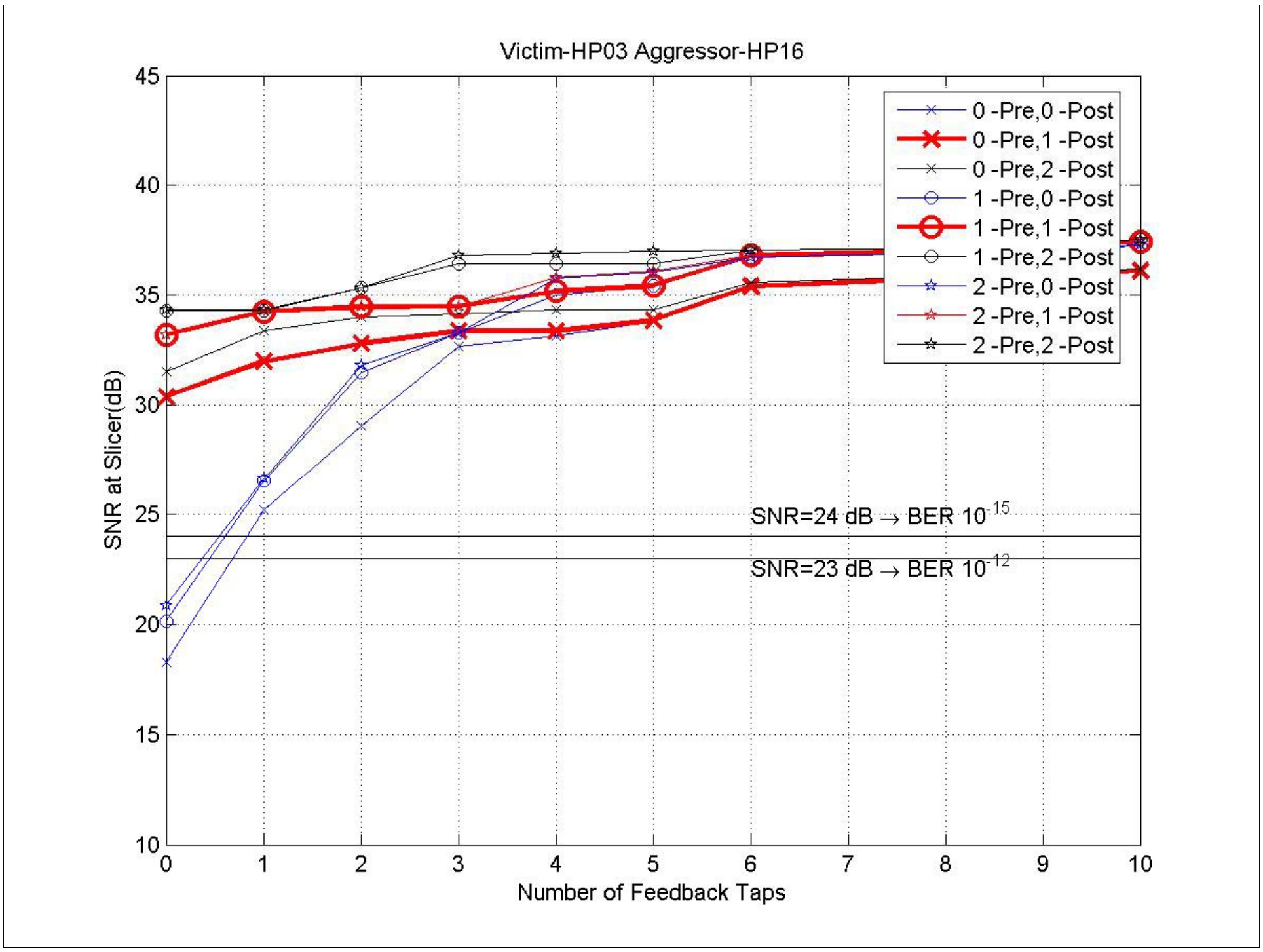
Victim-HP03 Aggressor-HP16
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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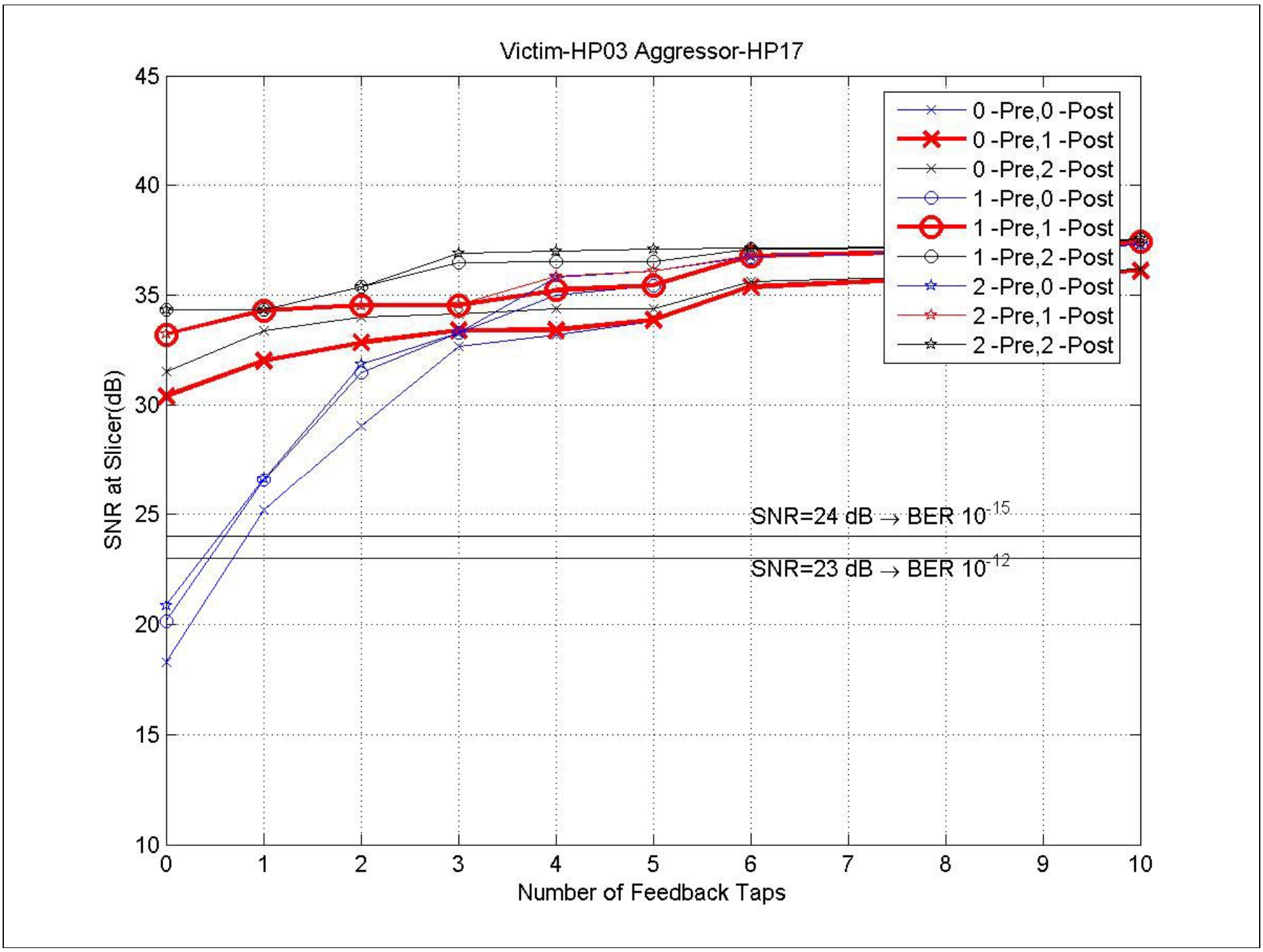
Victim-HP03 Aggressor-HP17
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
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SNR=24 dB → BER 10^-15
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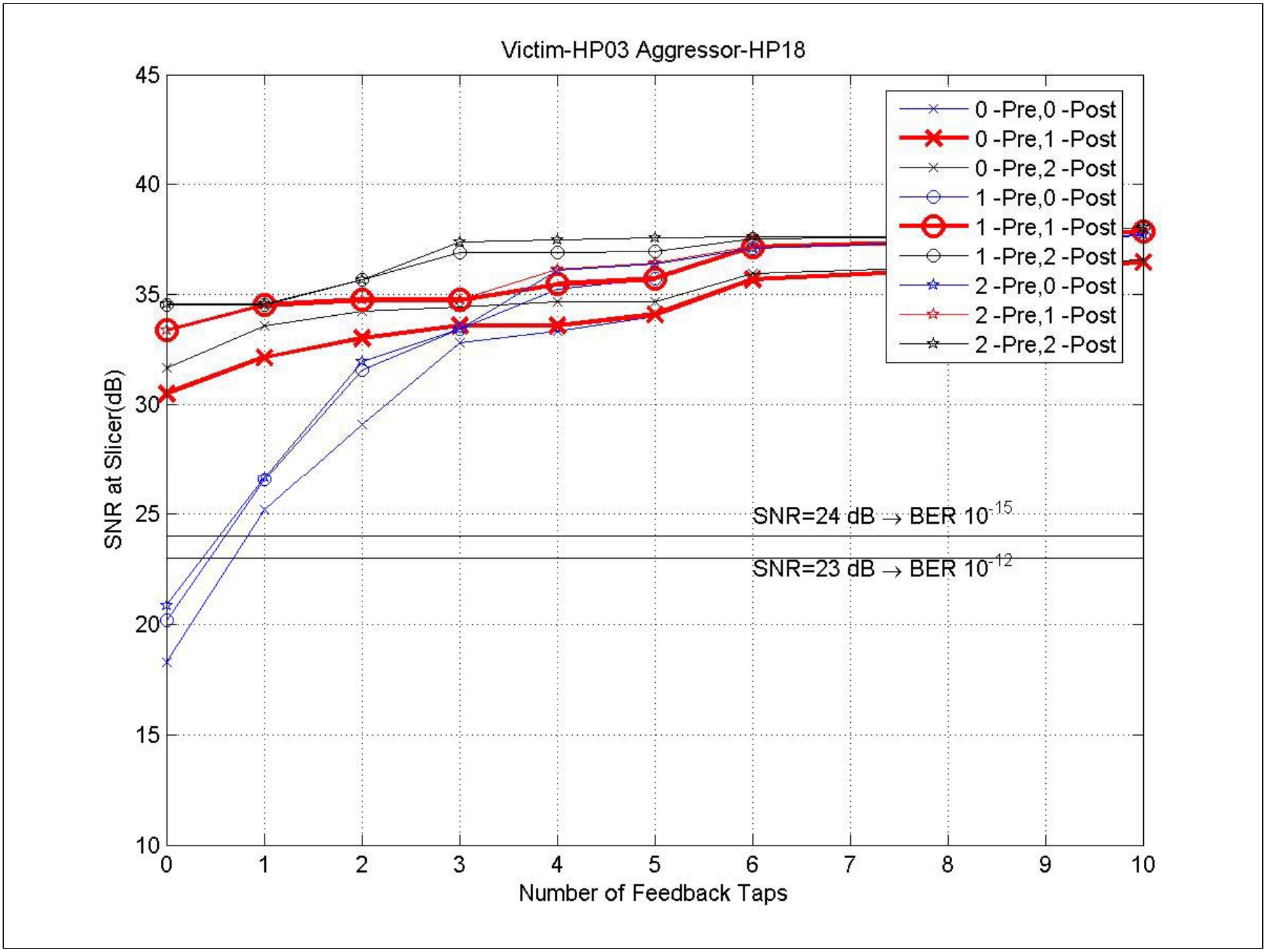
Victim-HP03 Aggressor-HP18
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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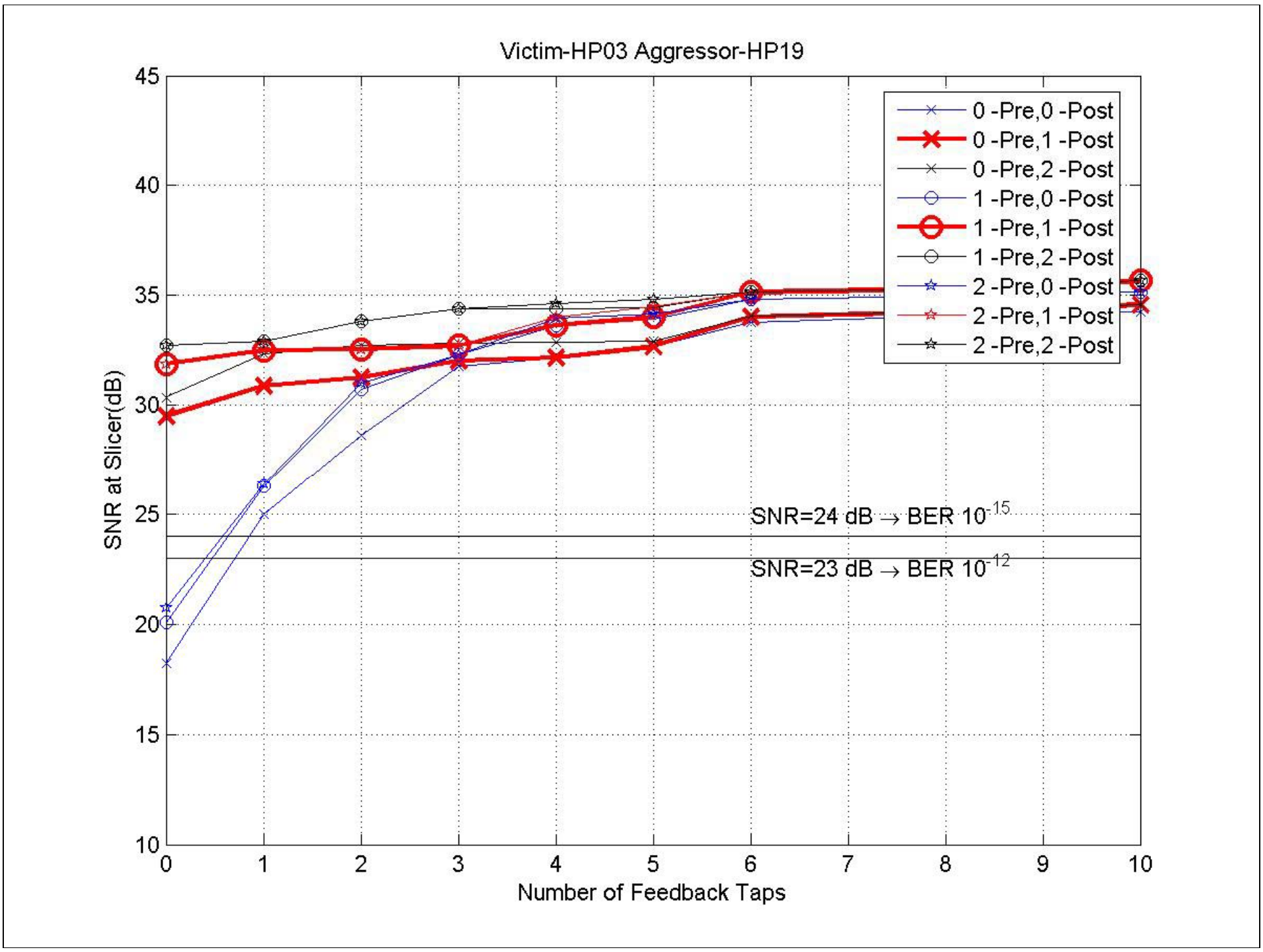
Victim-HP03 Aggressor-HP19
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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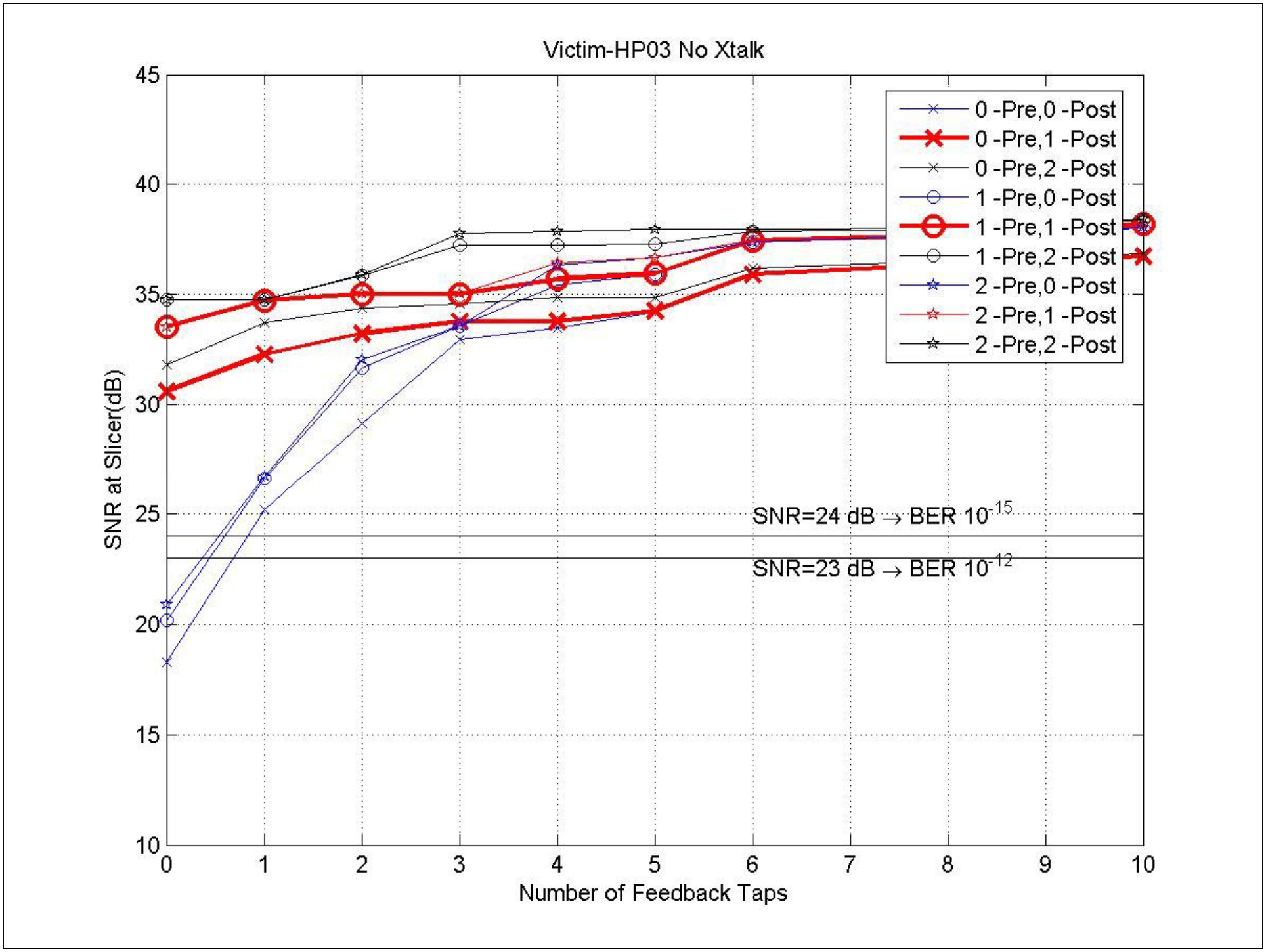
Victim-HP03 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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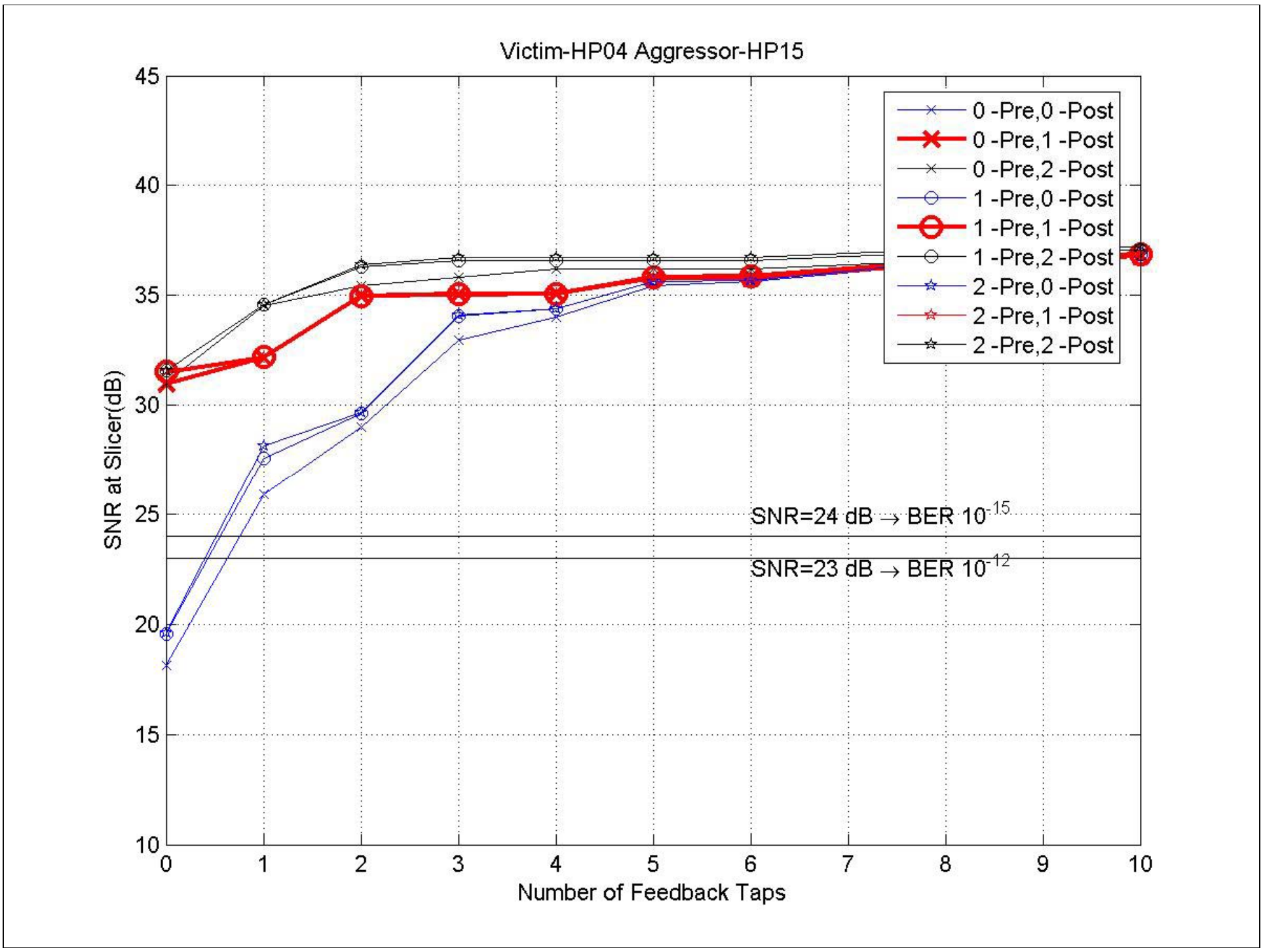
Victim-HP04 Aggressor-HP15
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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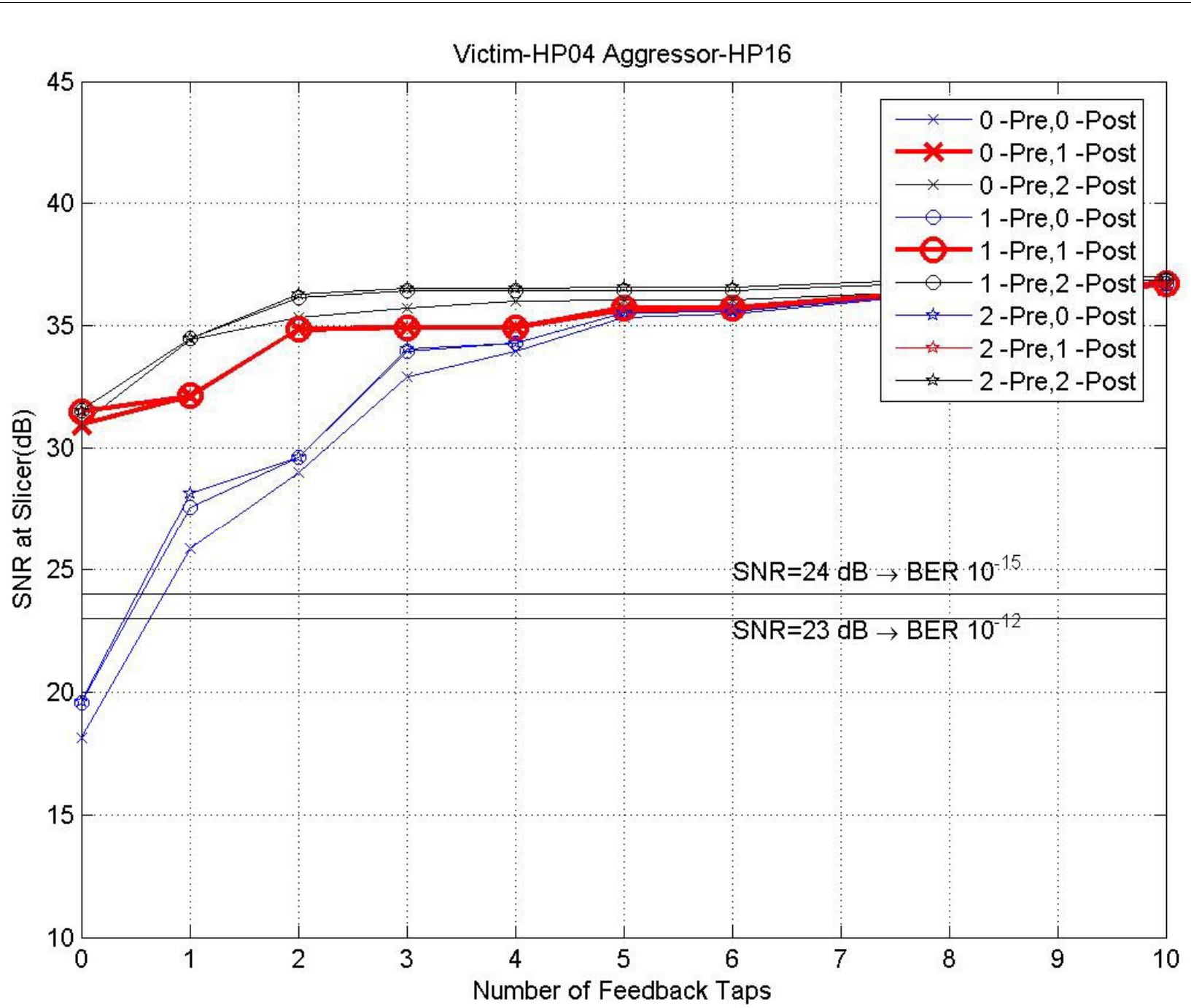
Victim-HP04 Aggressor-HP16
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
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2 -Pre,0 -Post
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2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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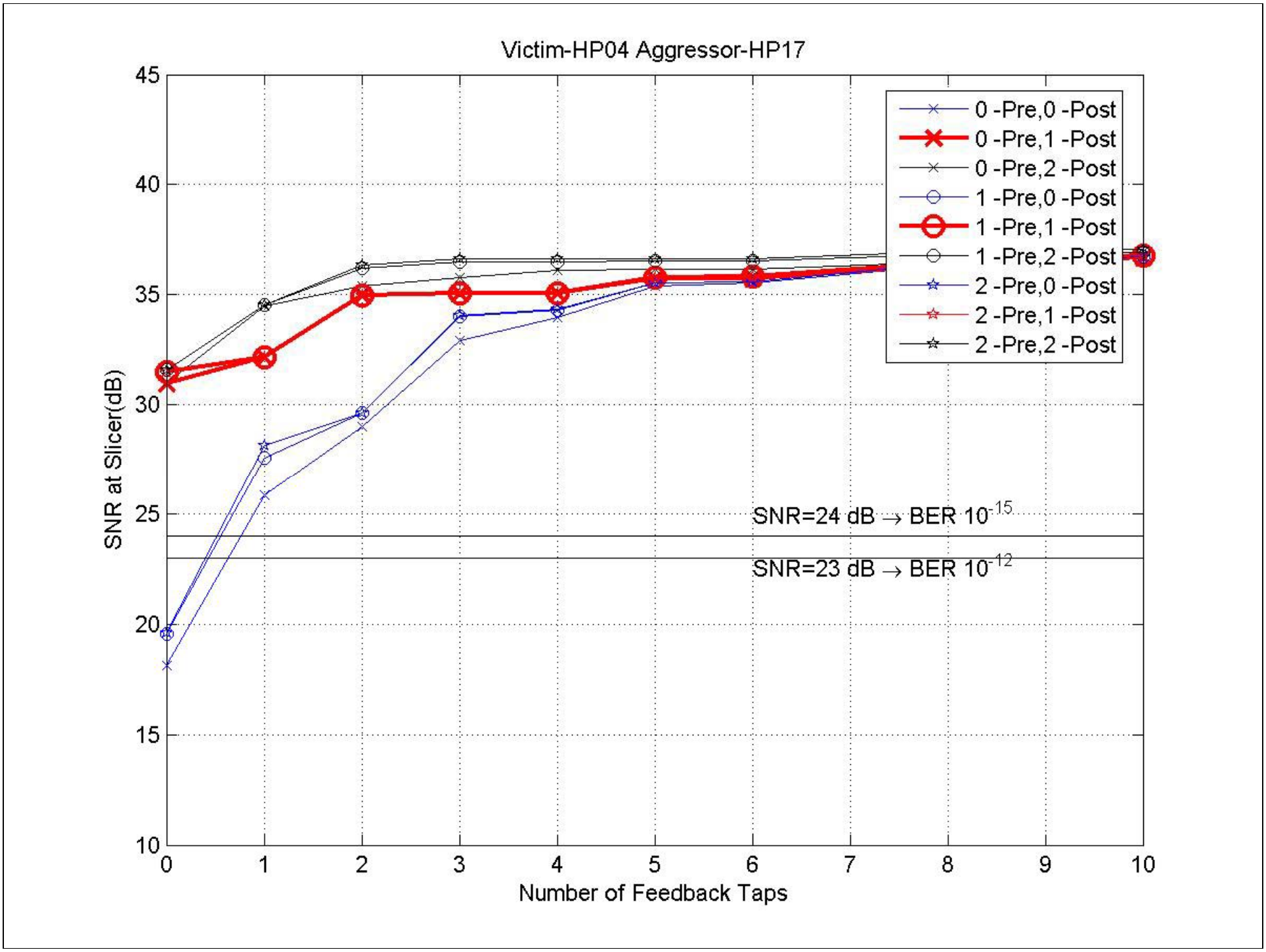
Victim-HP04 Aggressor-HP17
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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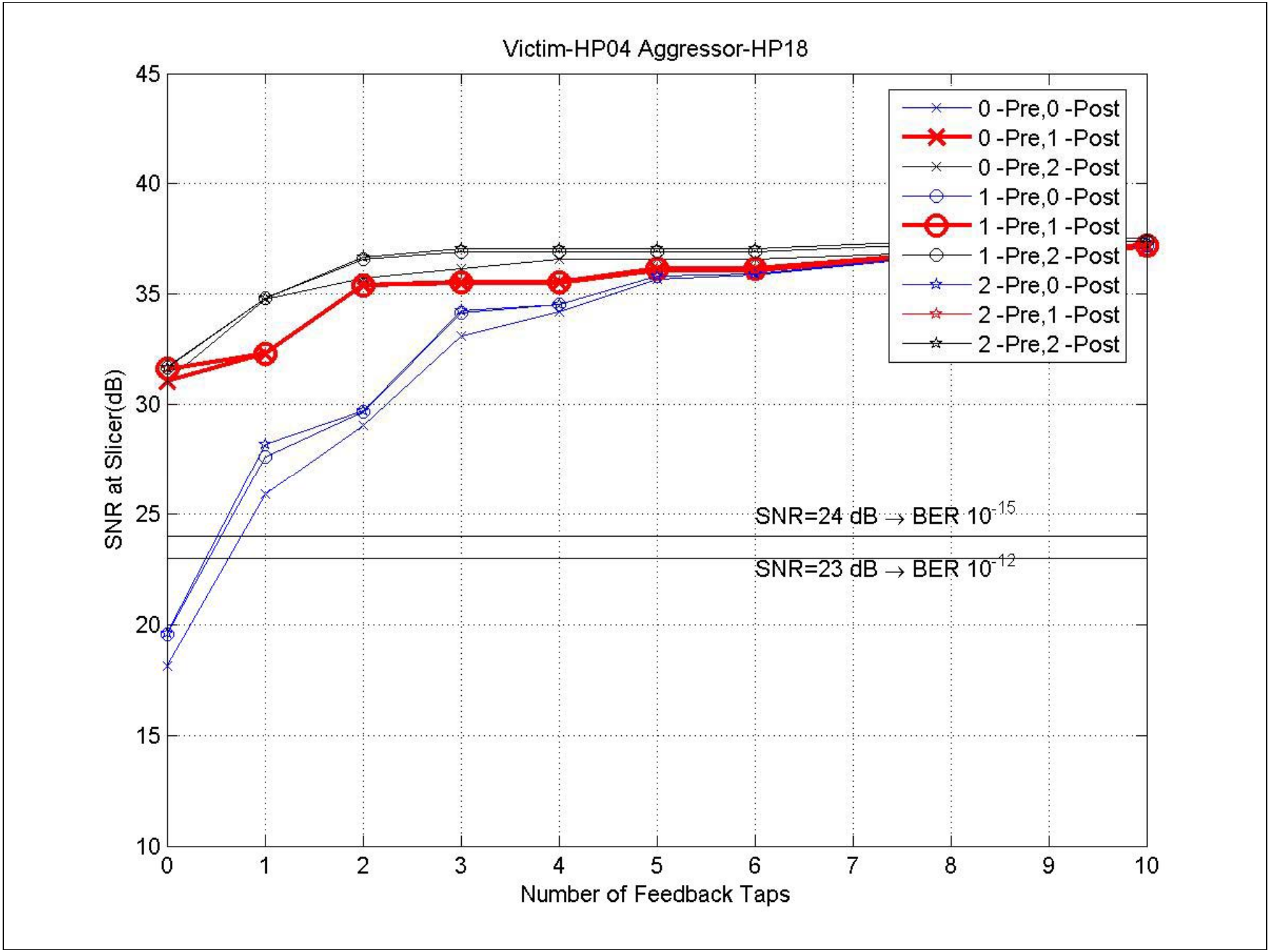
Victim-HP04 Aggressor-HP18
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
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2 -Pre,0 -Post
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2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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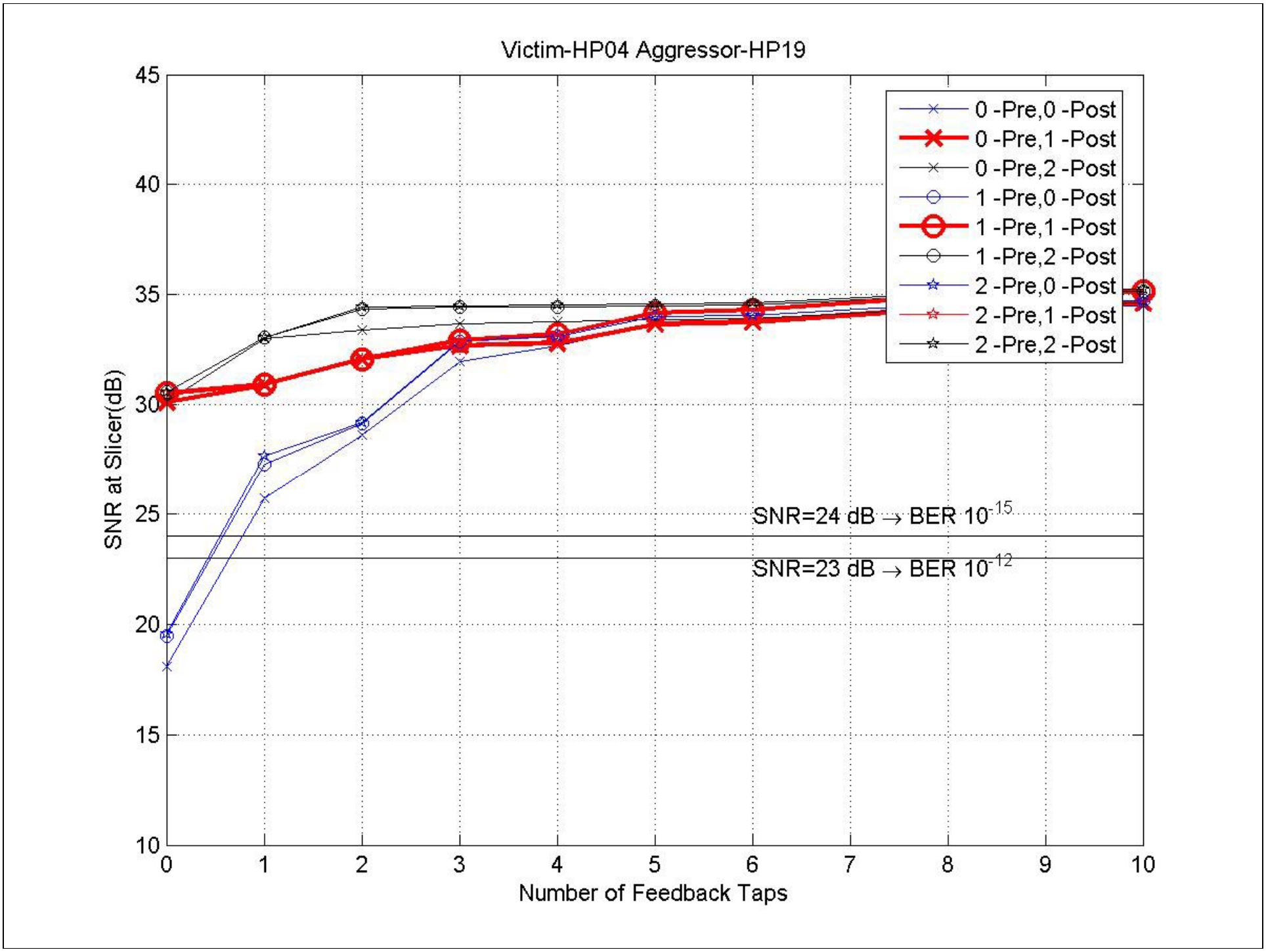
Victim-HP04 Aggressor-HP19
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
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1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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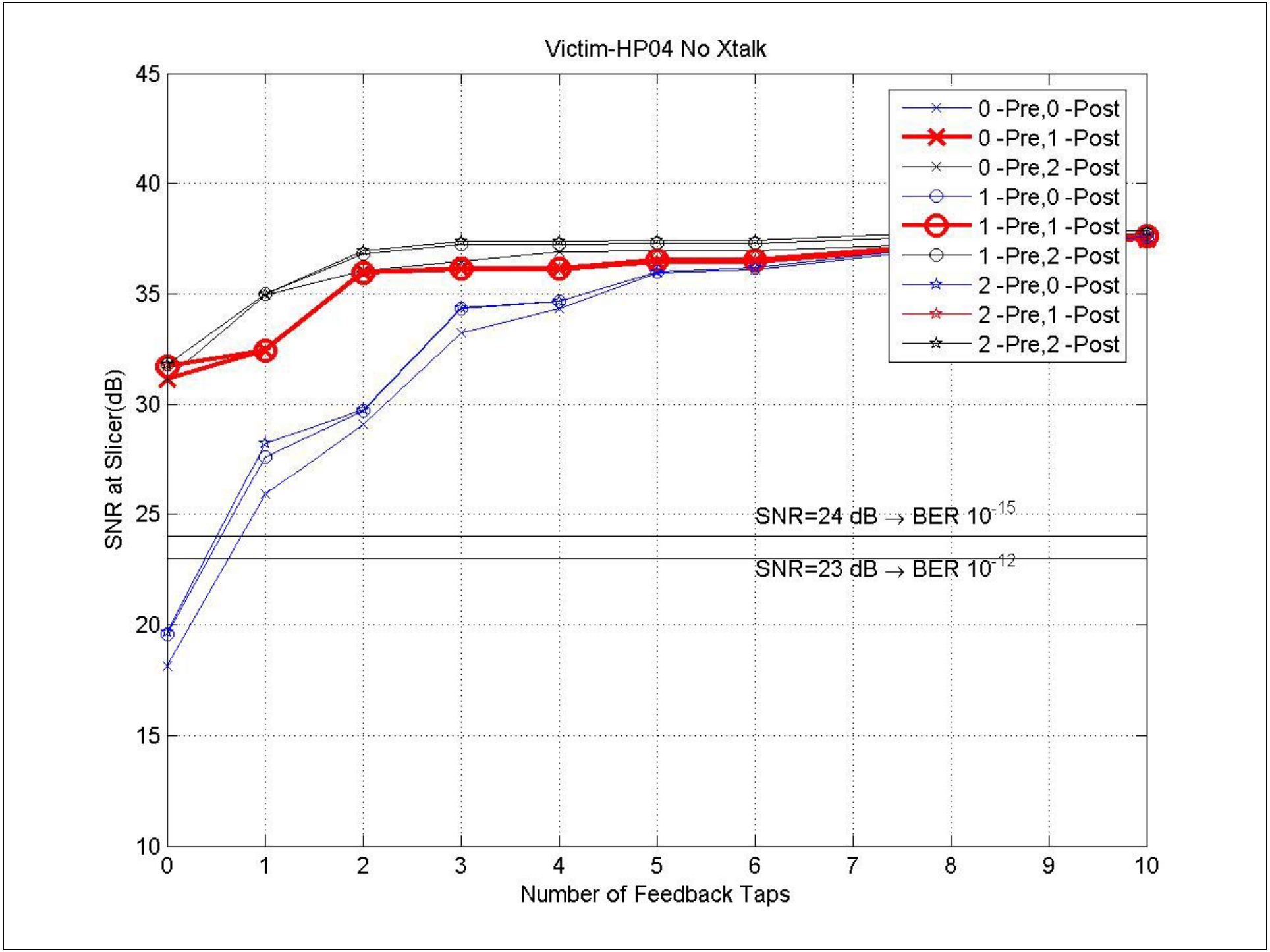
Victim-HP04 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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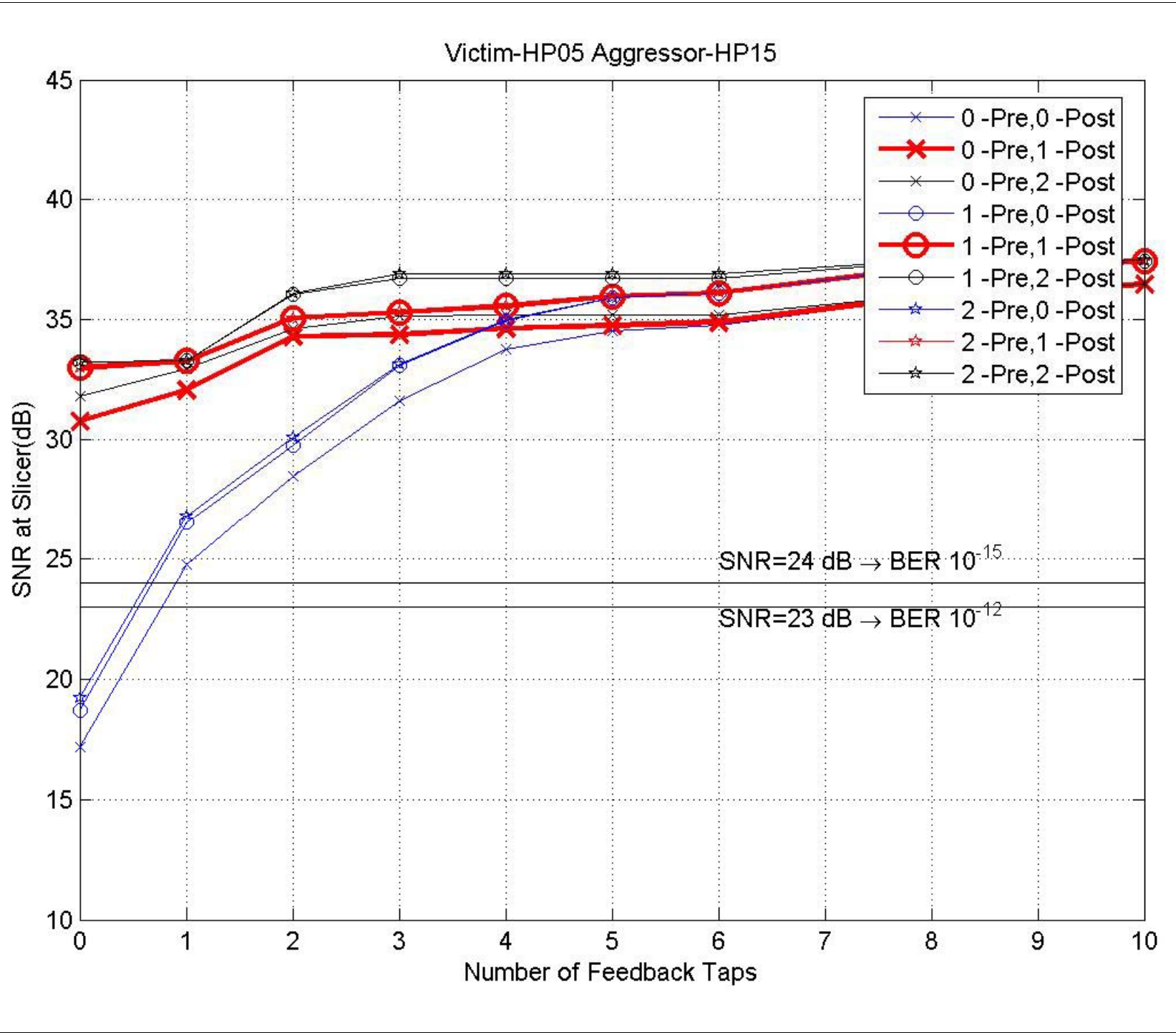
Victim-HP05 Aggressor-HP15
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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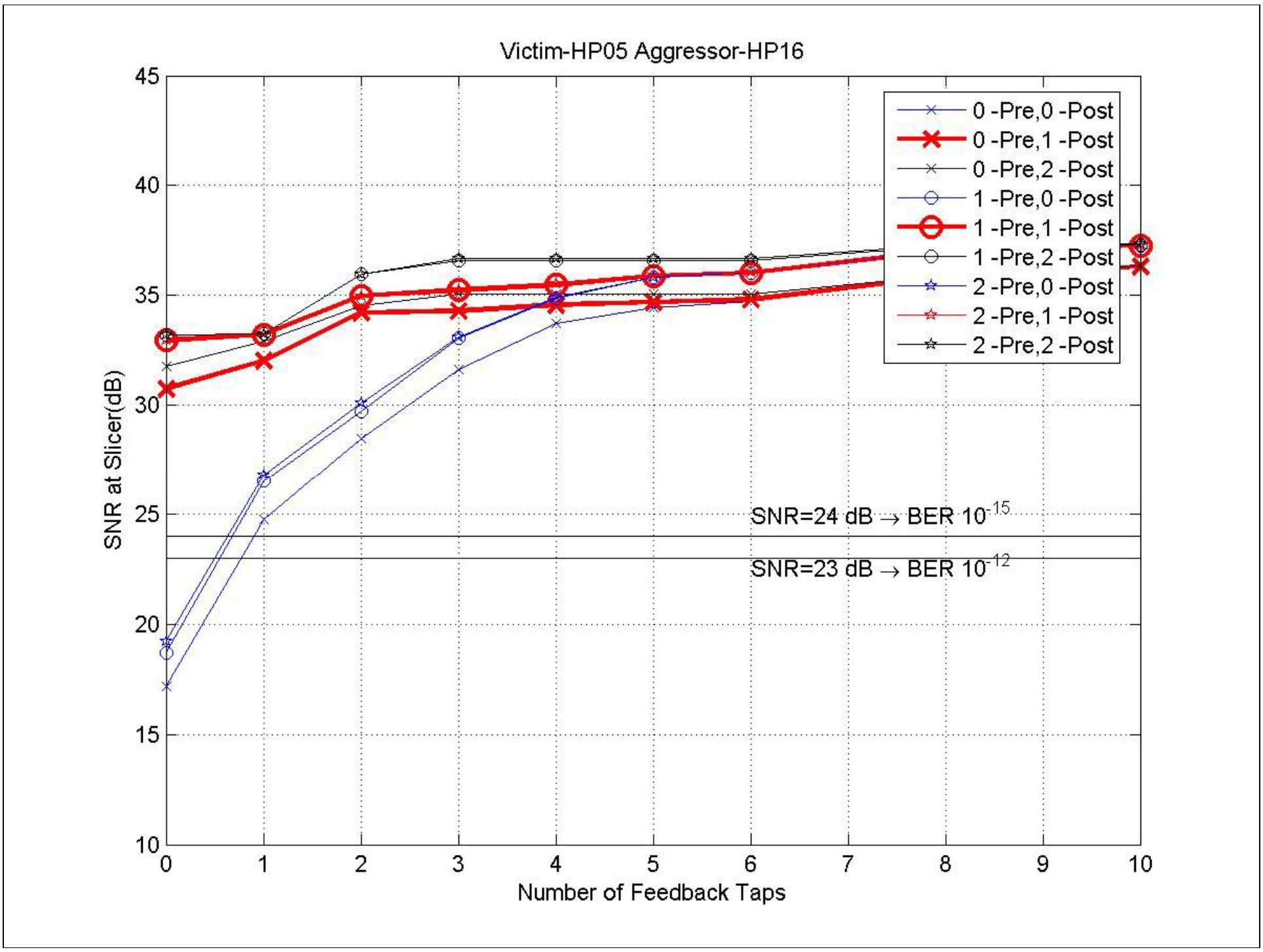
Victim-HP05 Aggressor-HP16
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
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1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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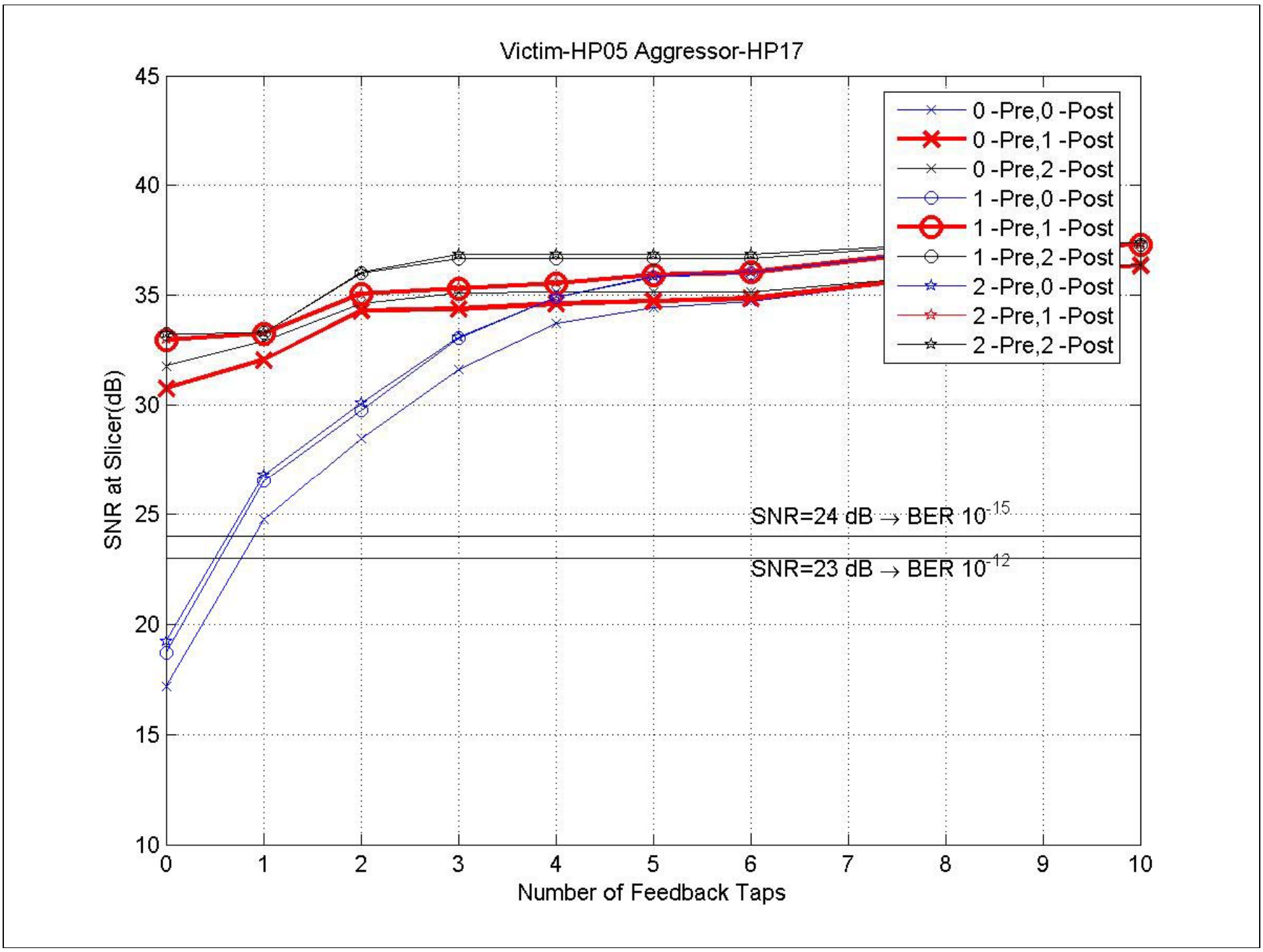
Victim-HP05 Aggressor-HP17
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
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2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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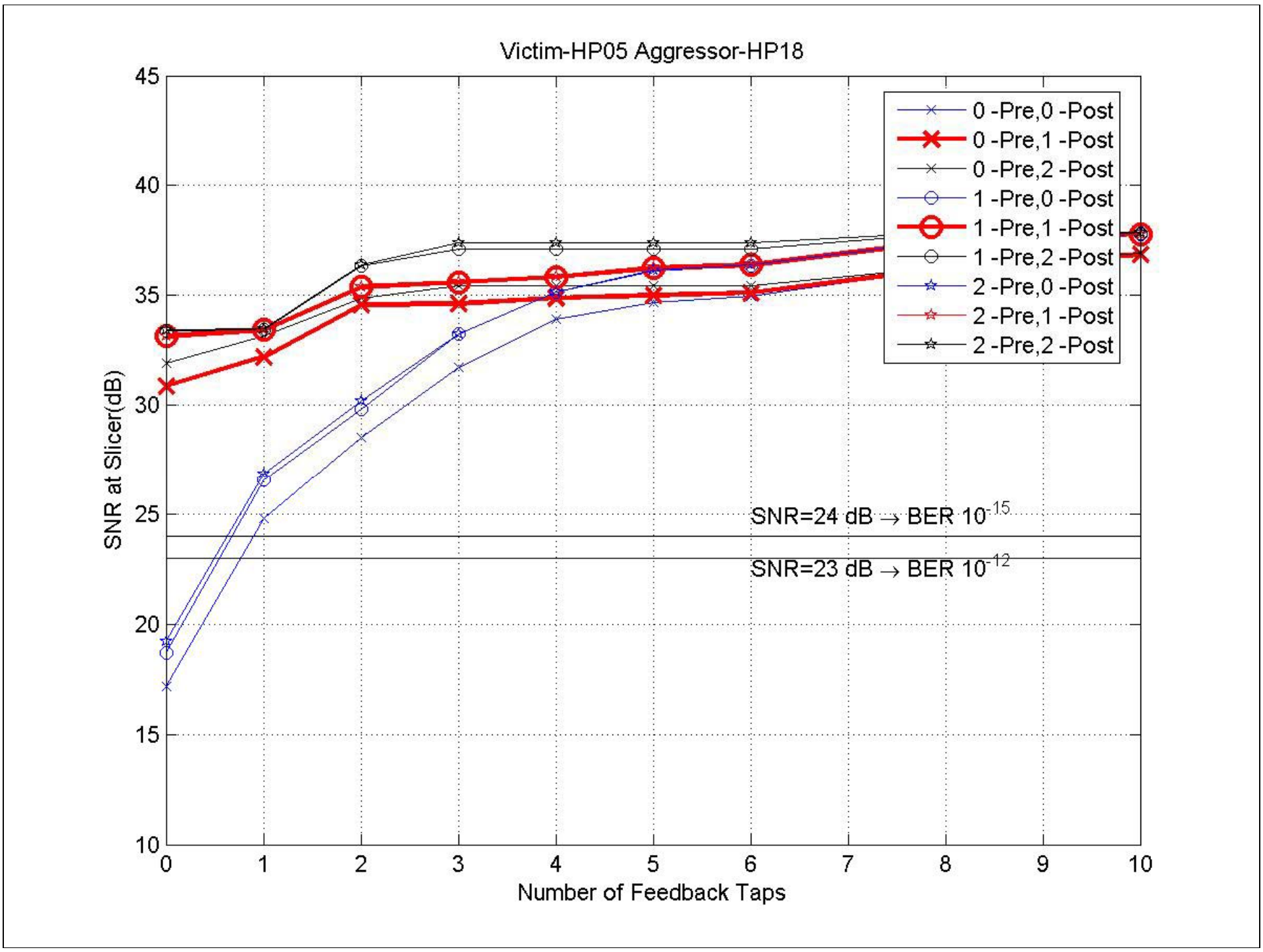
Victim-HP05 Aggressor-HP18
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
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2 -Pre,0 -Post
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2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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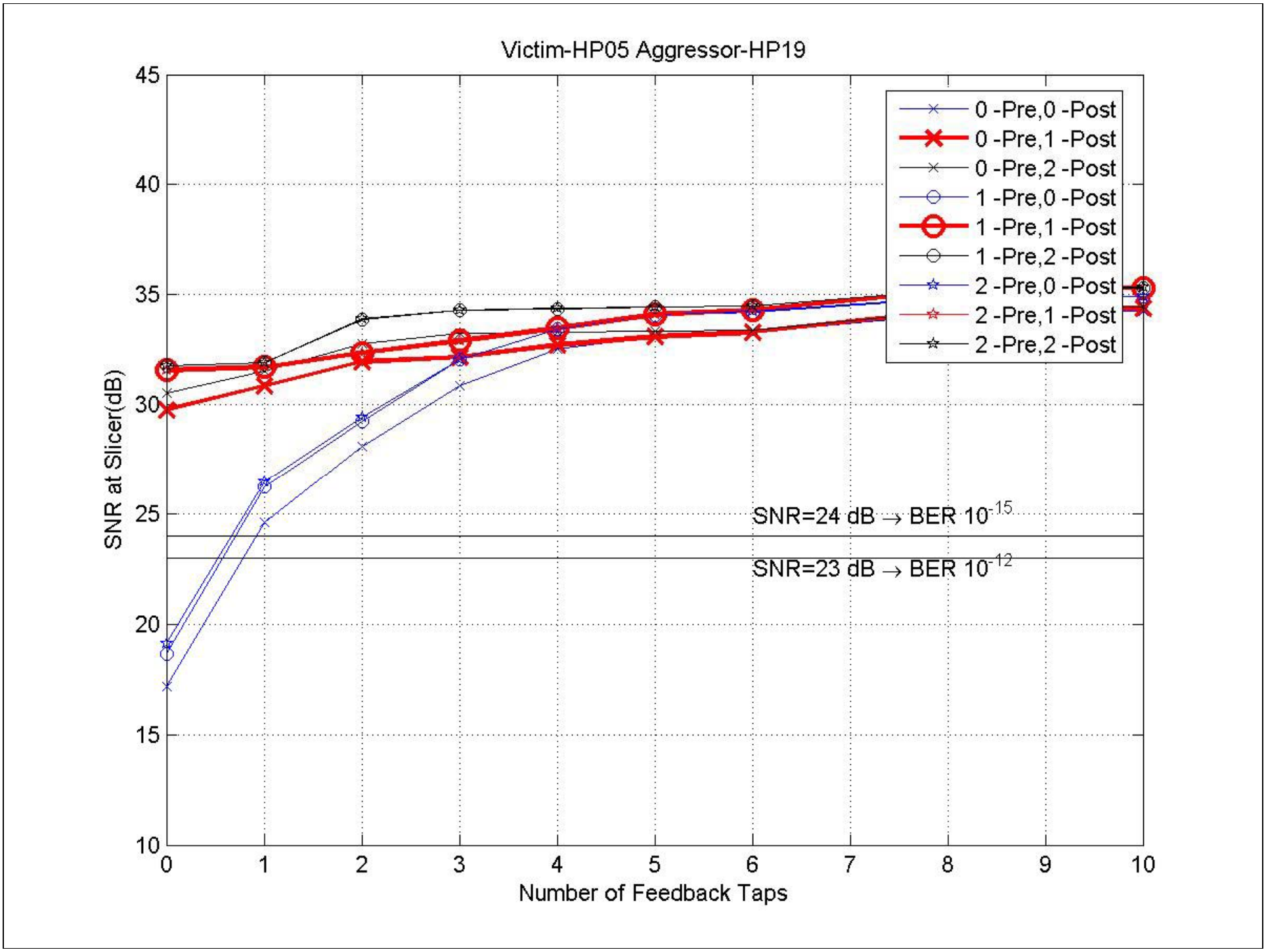
Victim-HP05 Aggressor-HP19
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
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1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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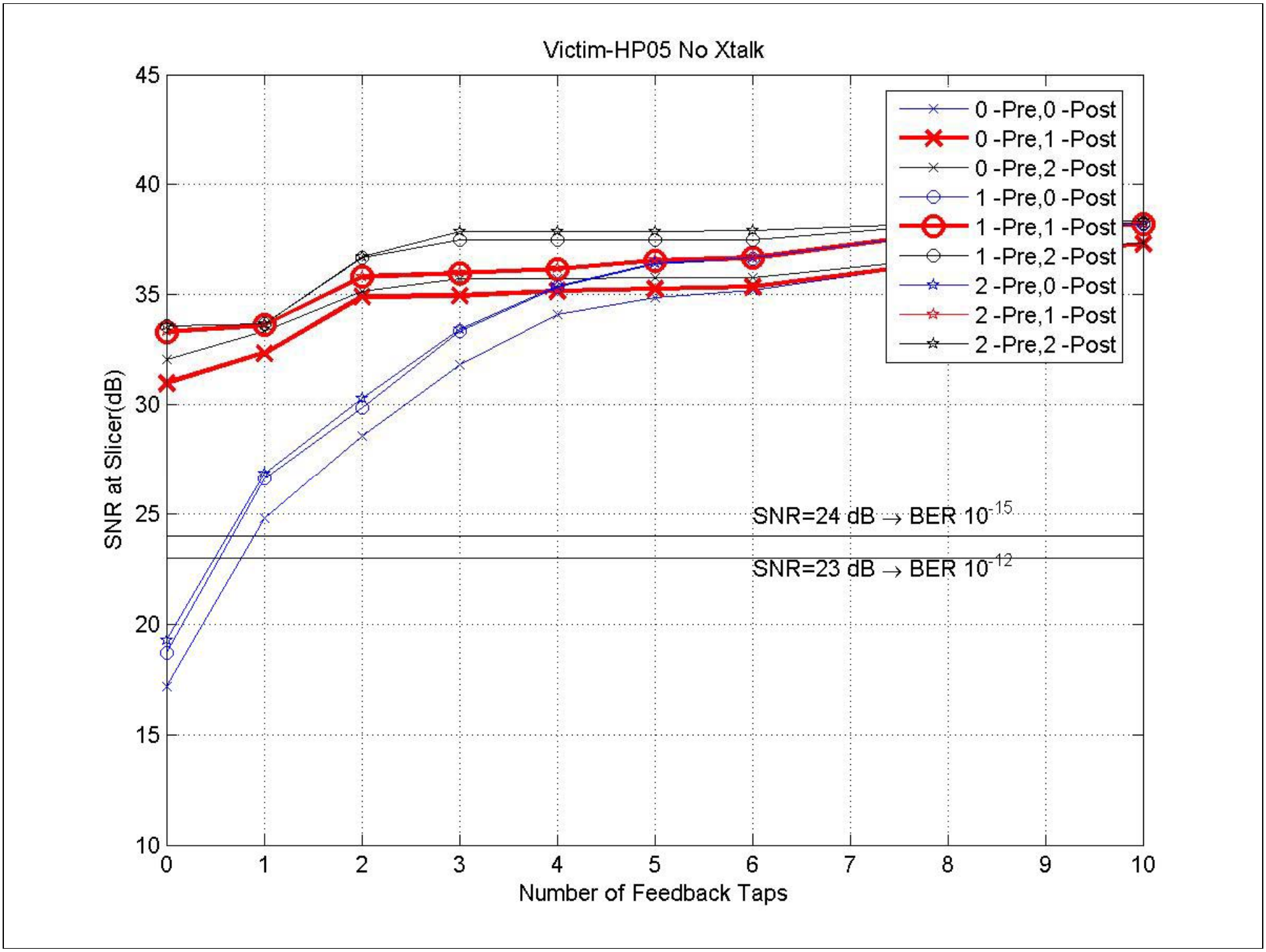
Victim-HP05 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
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1 -Pre,2 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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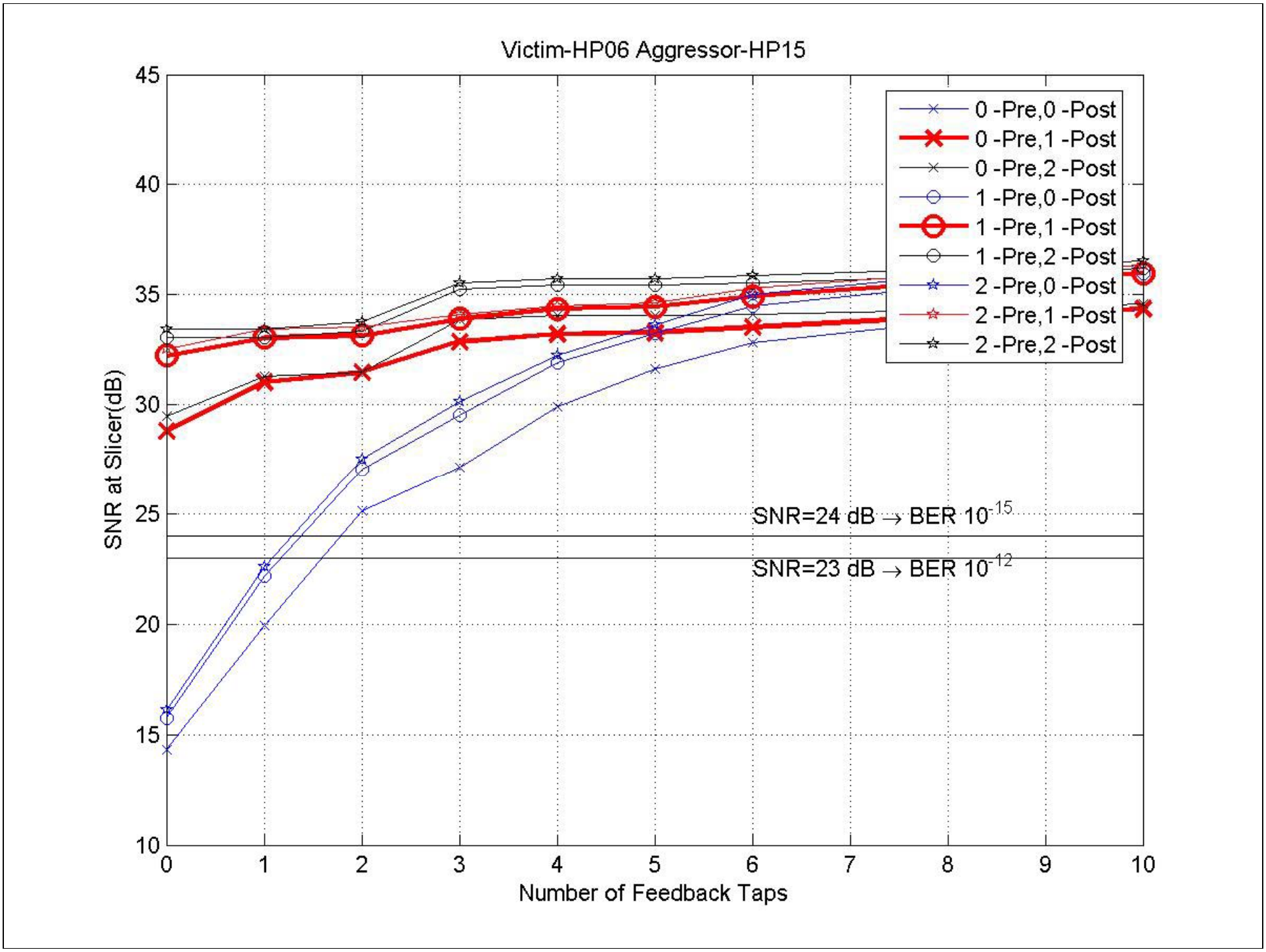
Victim-HP06 Aggressor-HP15
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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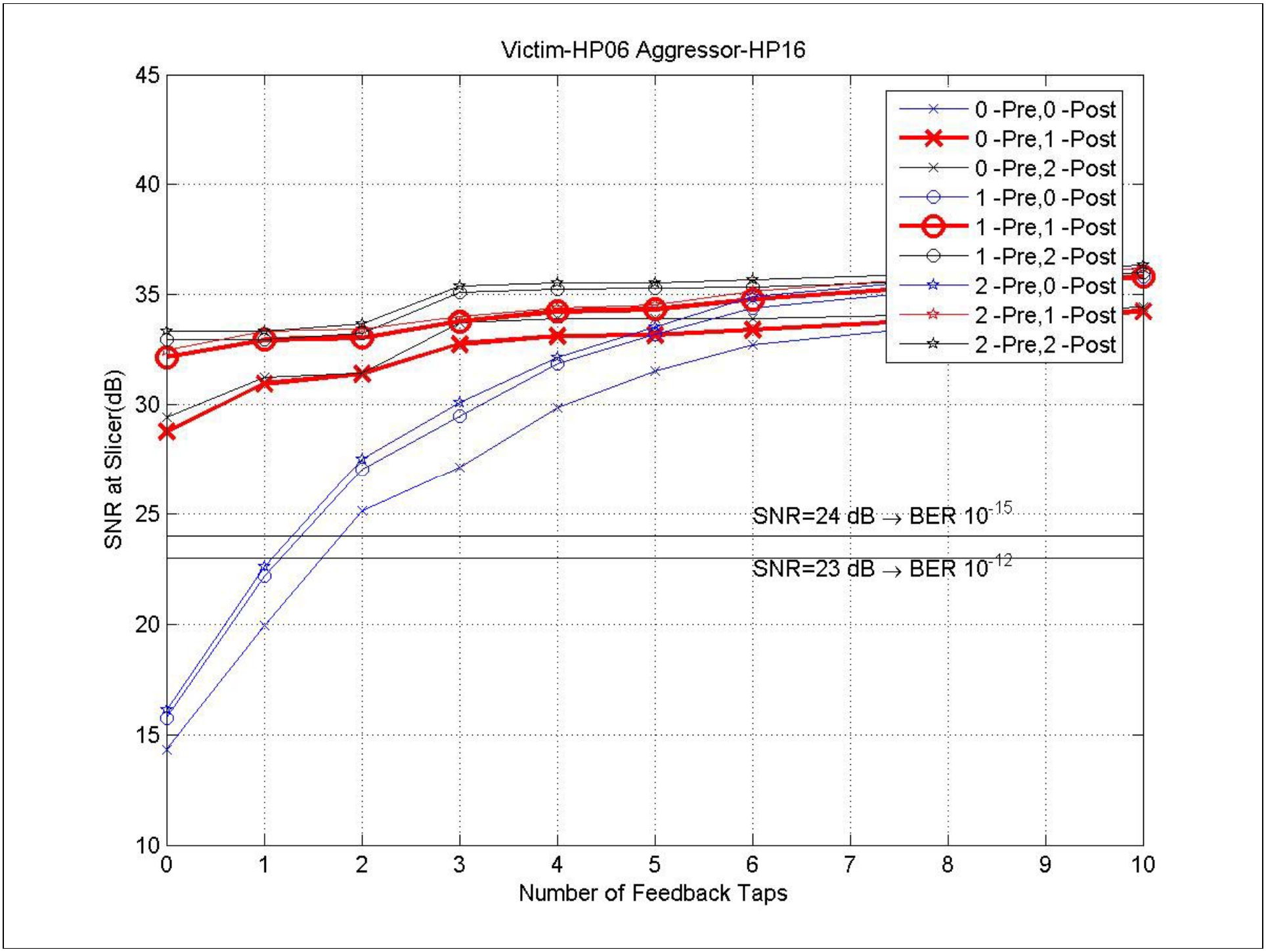
Victim-HP06 Aggressor-HP16
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
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2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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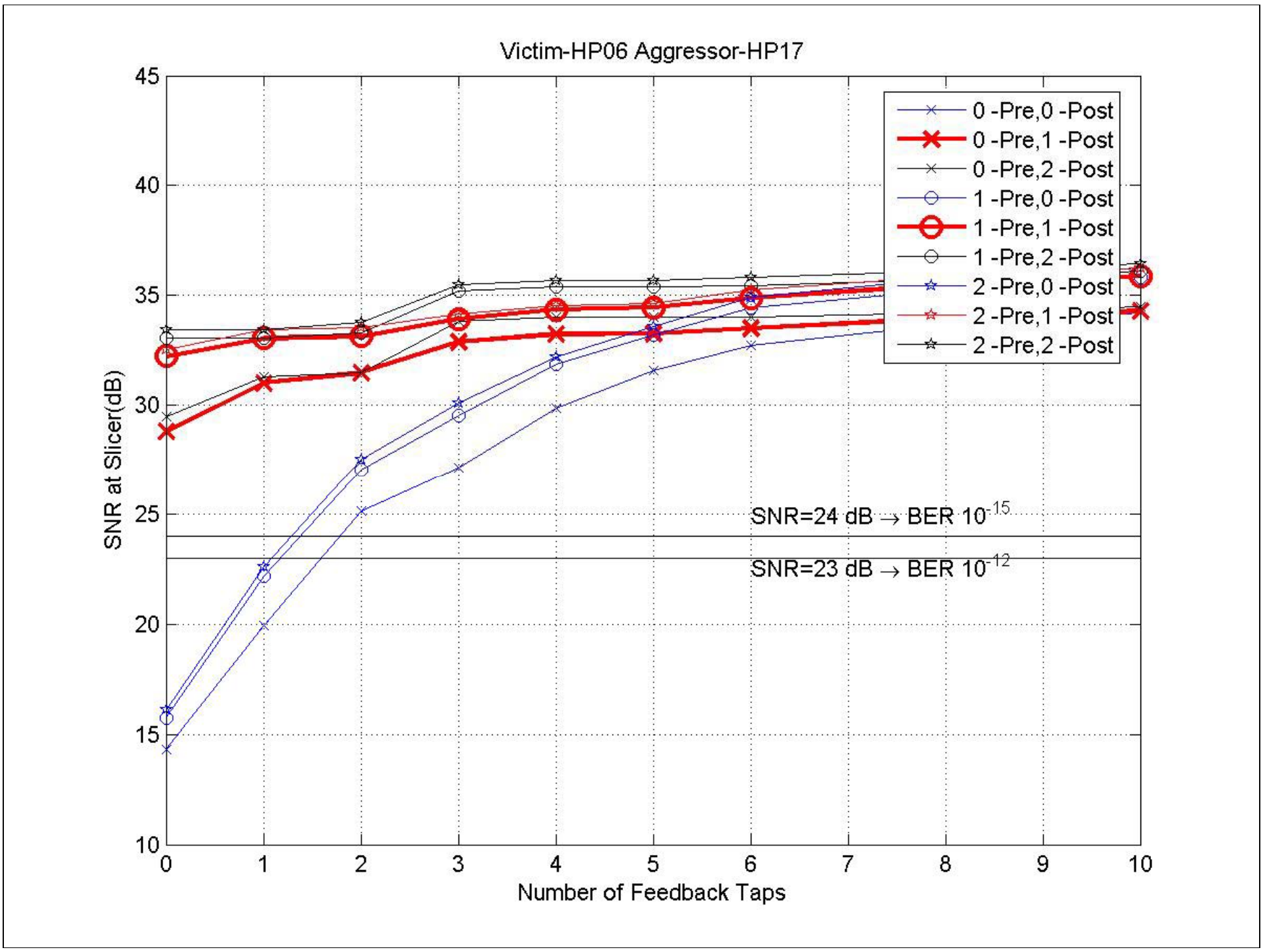
Victim-HP06 Aggressor-HP17
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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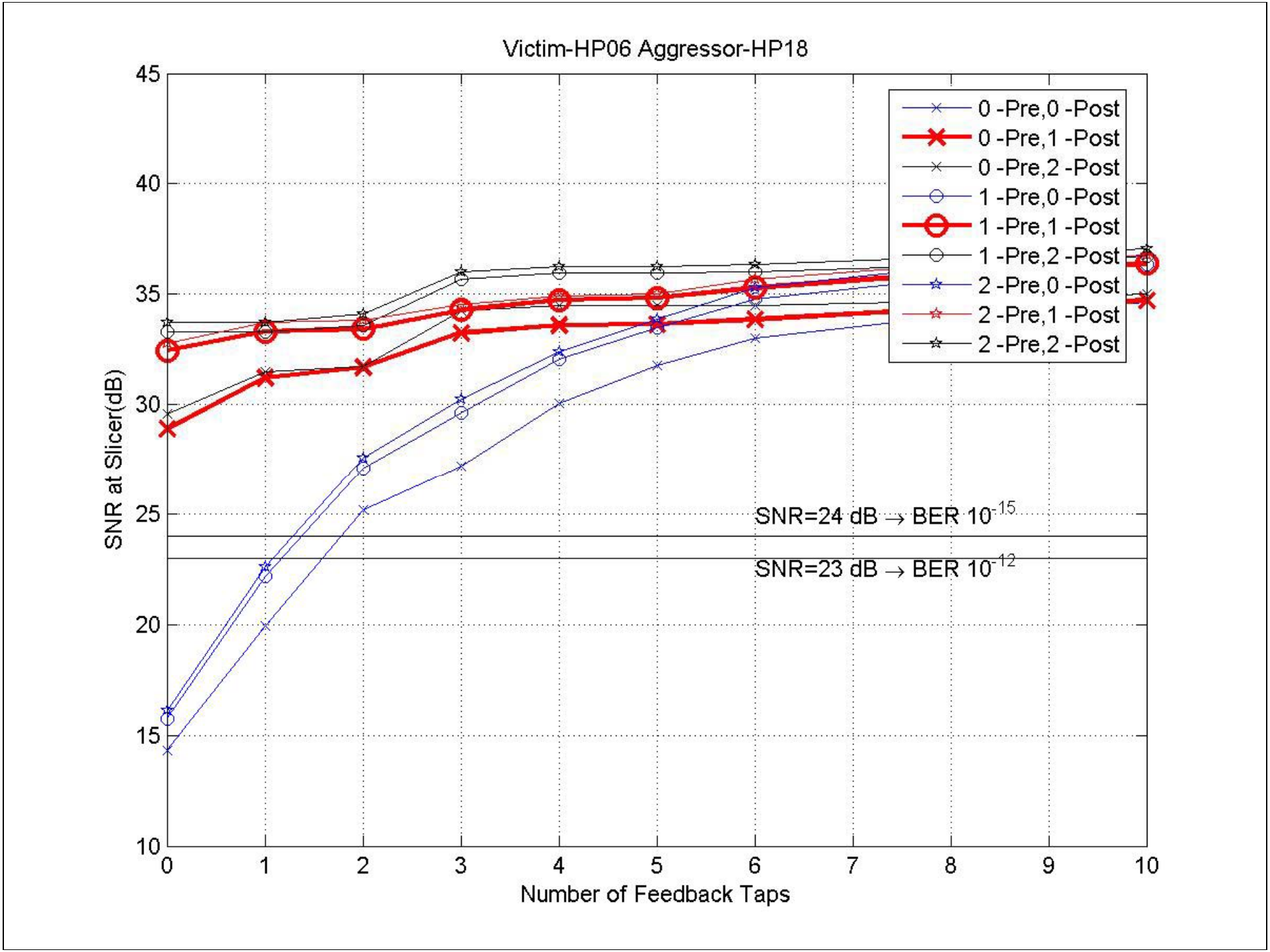
Victim-HP06 Aggressor-HP18
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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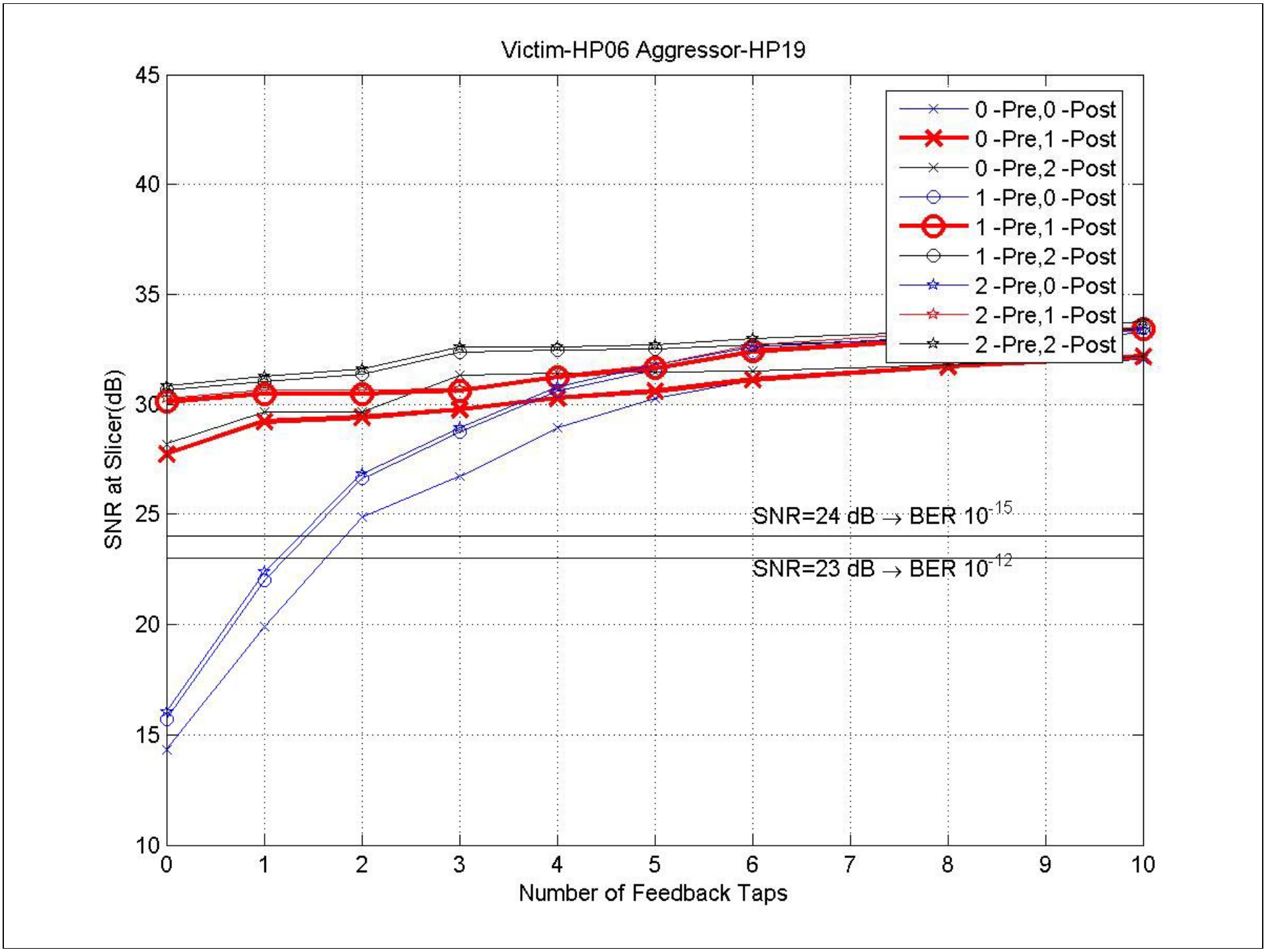
Victim-HP06 Aggressor-HP19
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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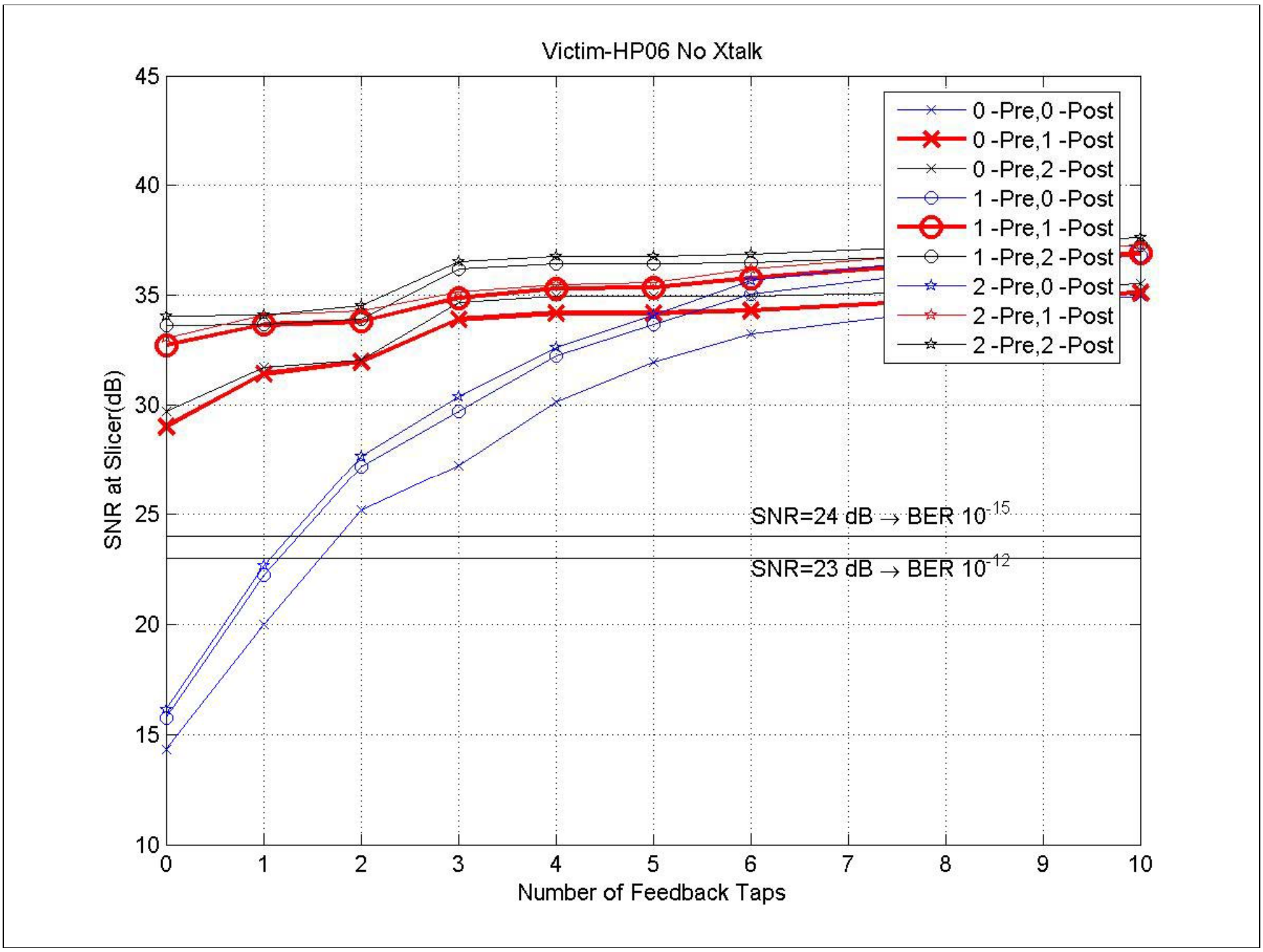
Victim-HP06 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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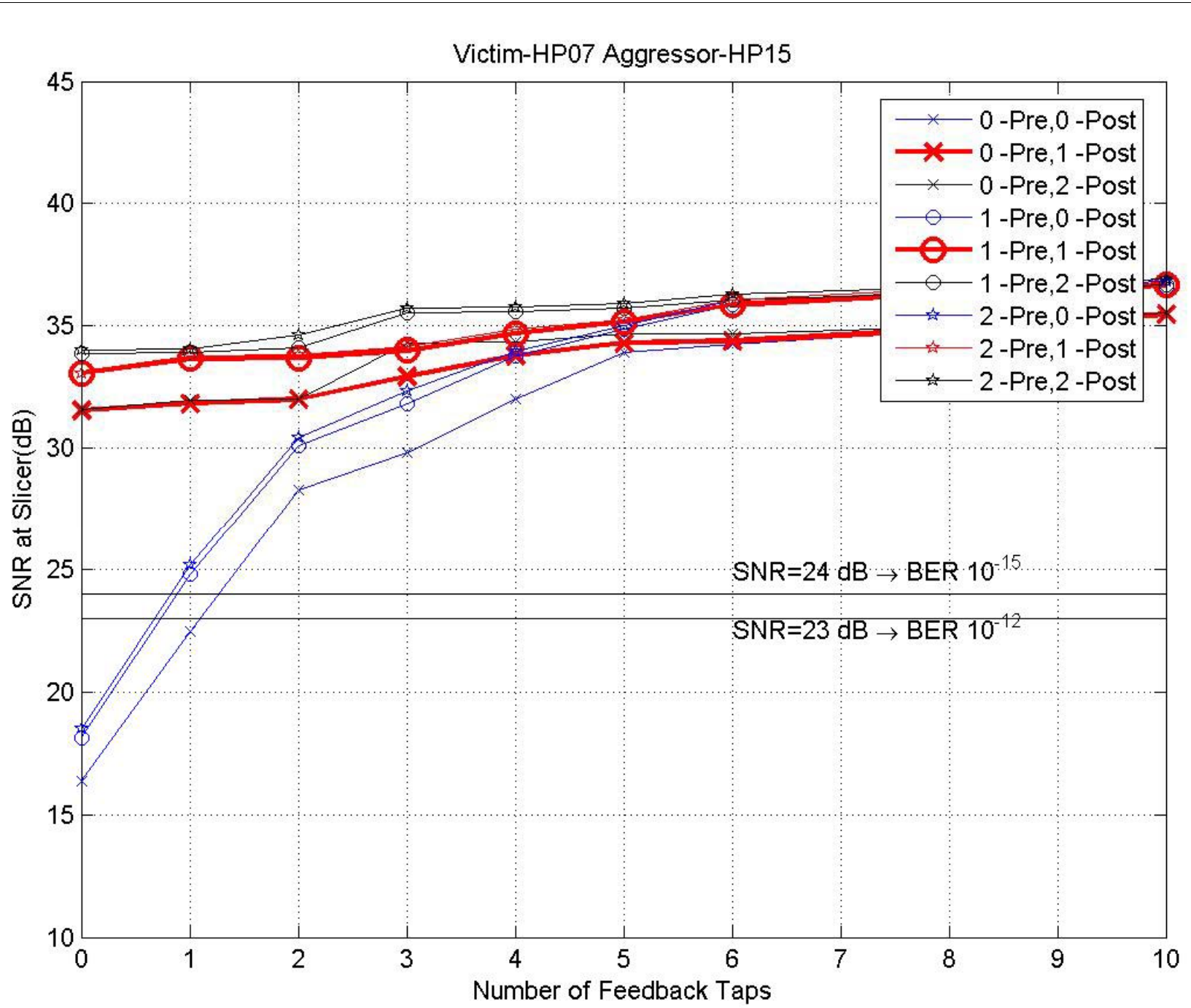
Victim-HP07 Aggressor-HP15
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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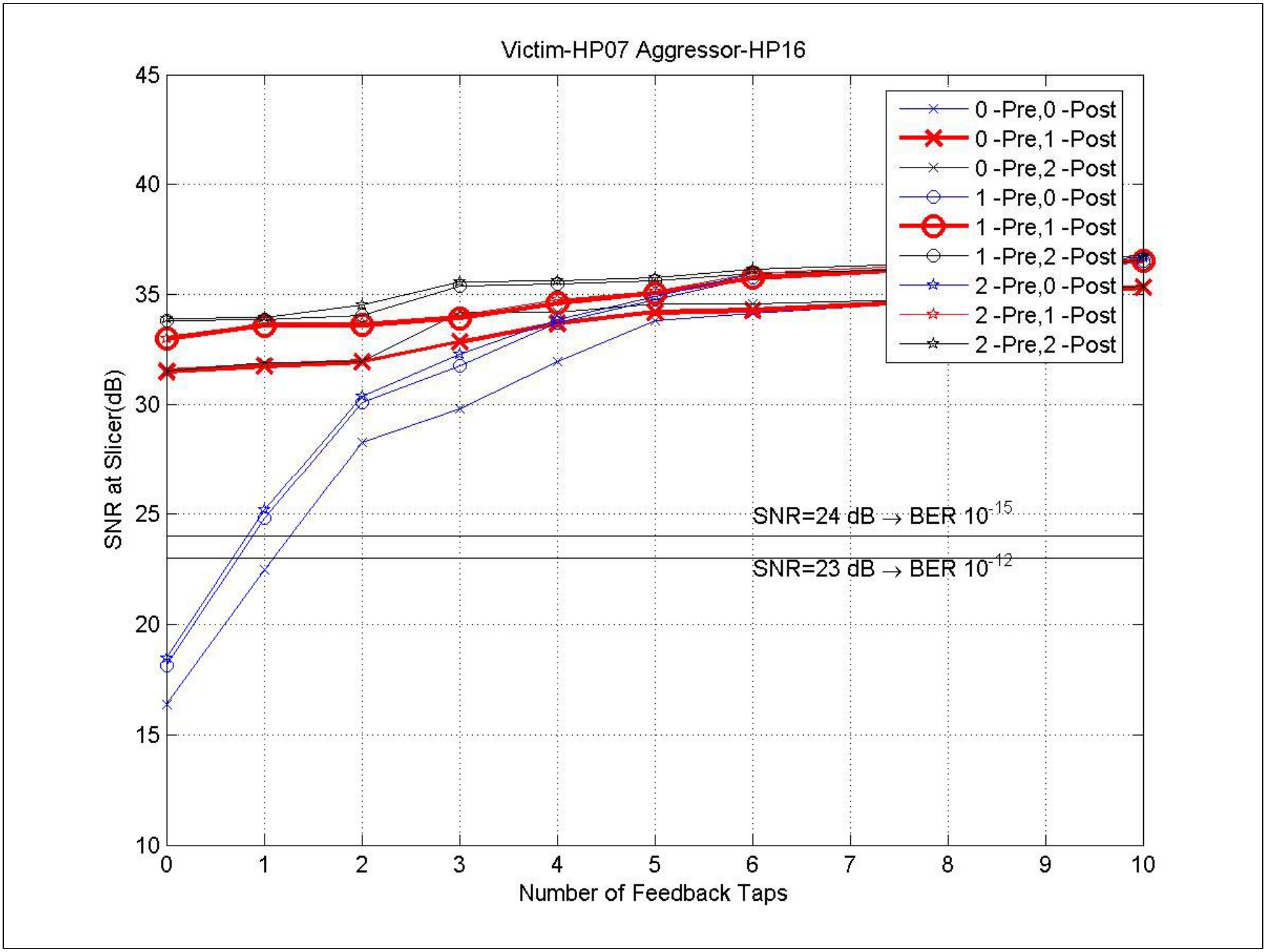
Victim-HP07 Aggressor-HP16
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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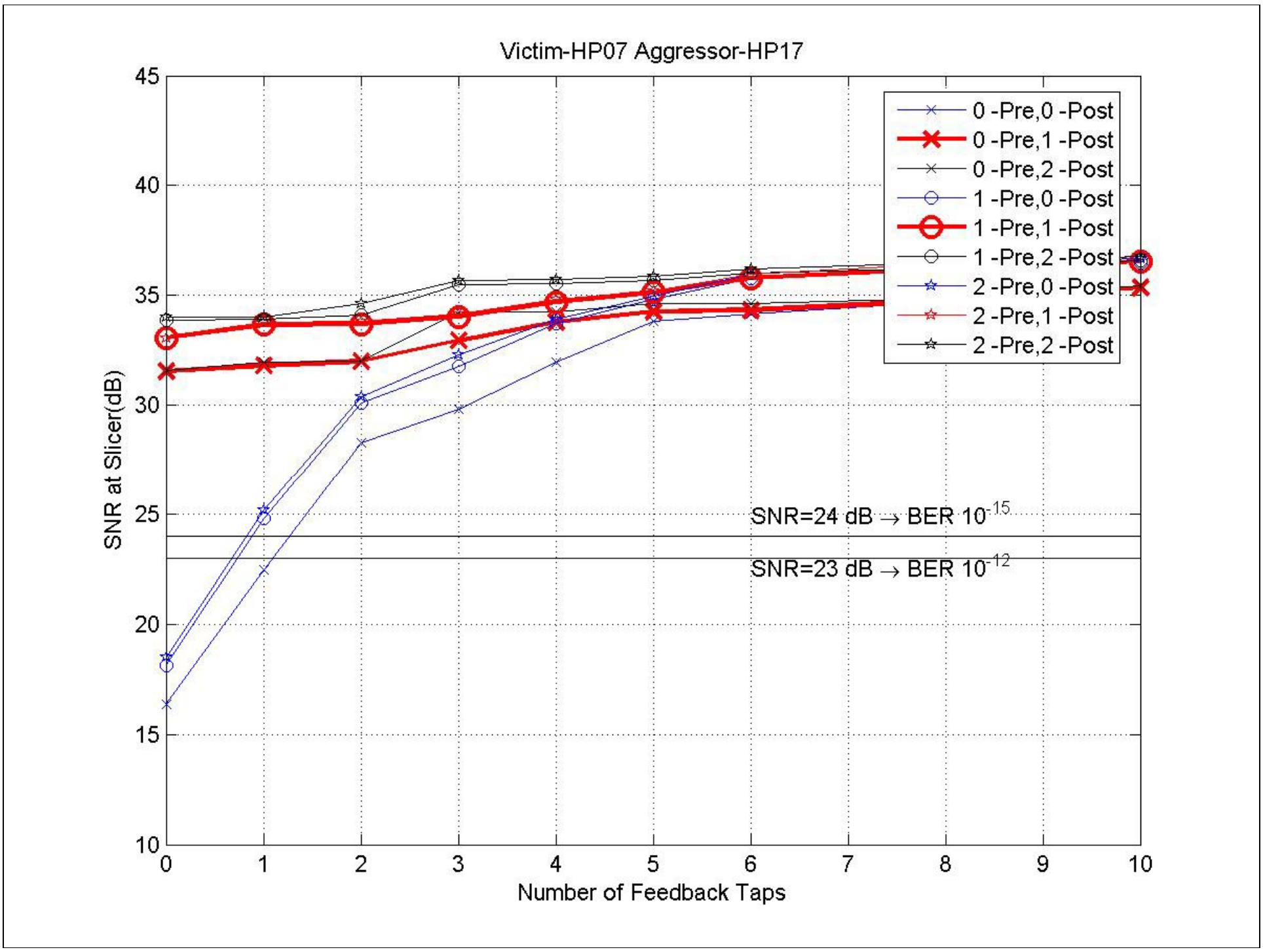
Victim-HP07 Aggressor-HP17
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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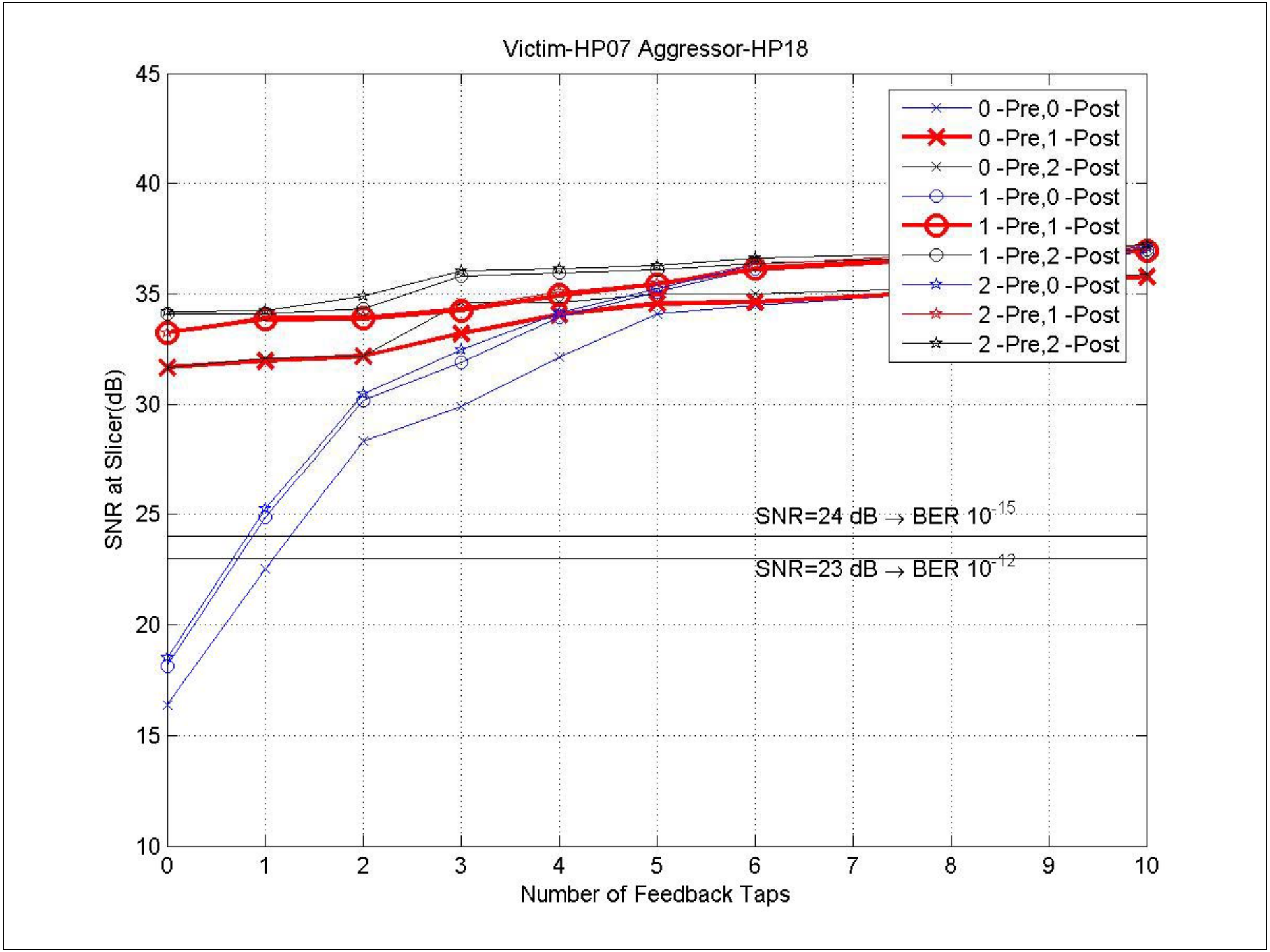
Victim-HP07 Aggressor-HP18
SNR at Slicer(dB)
Number of Feedback Taps
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0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
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SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
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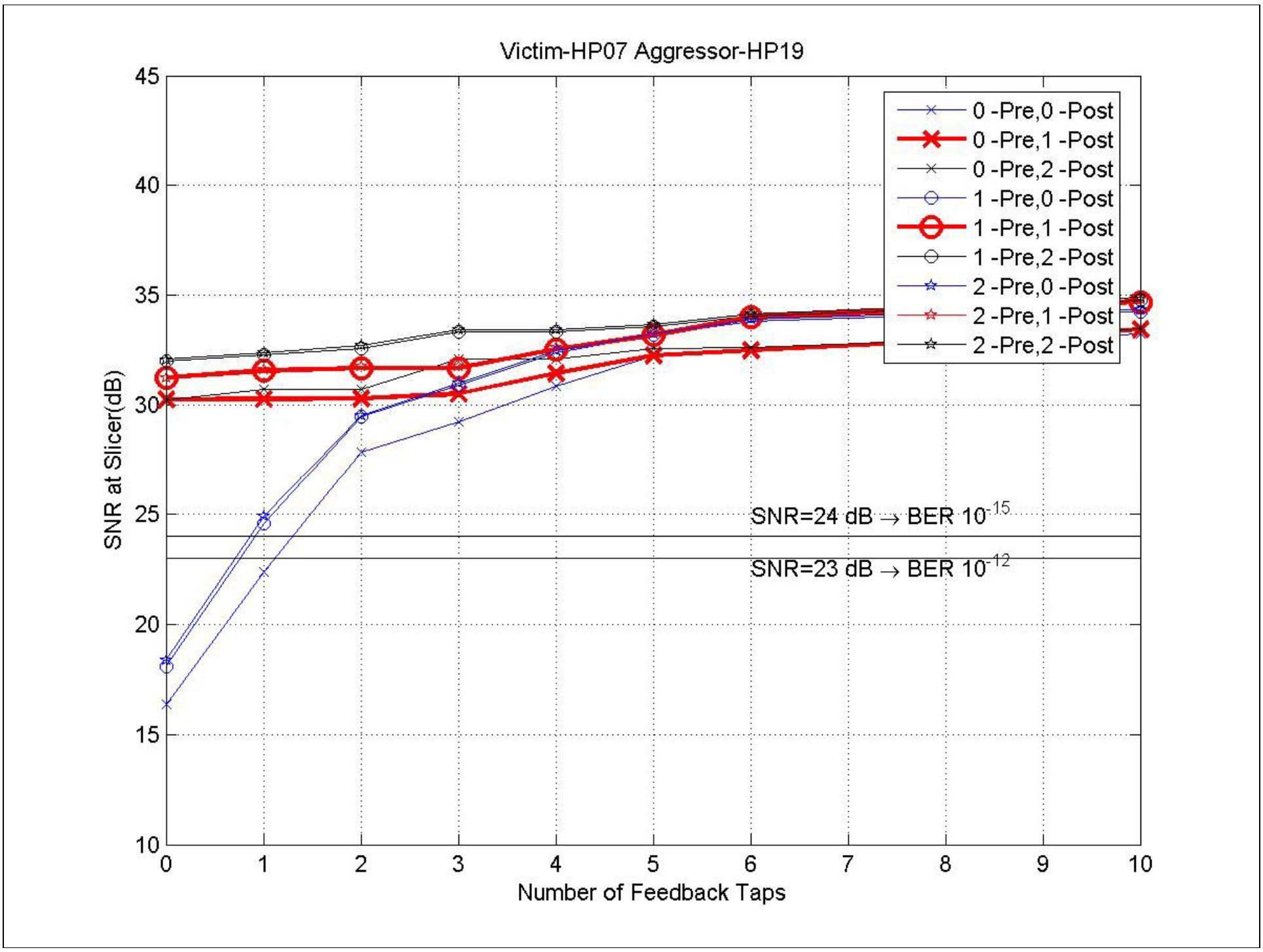
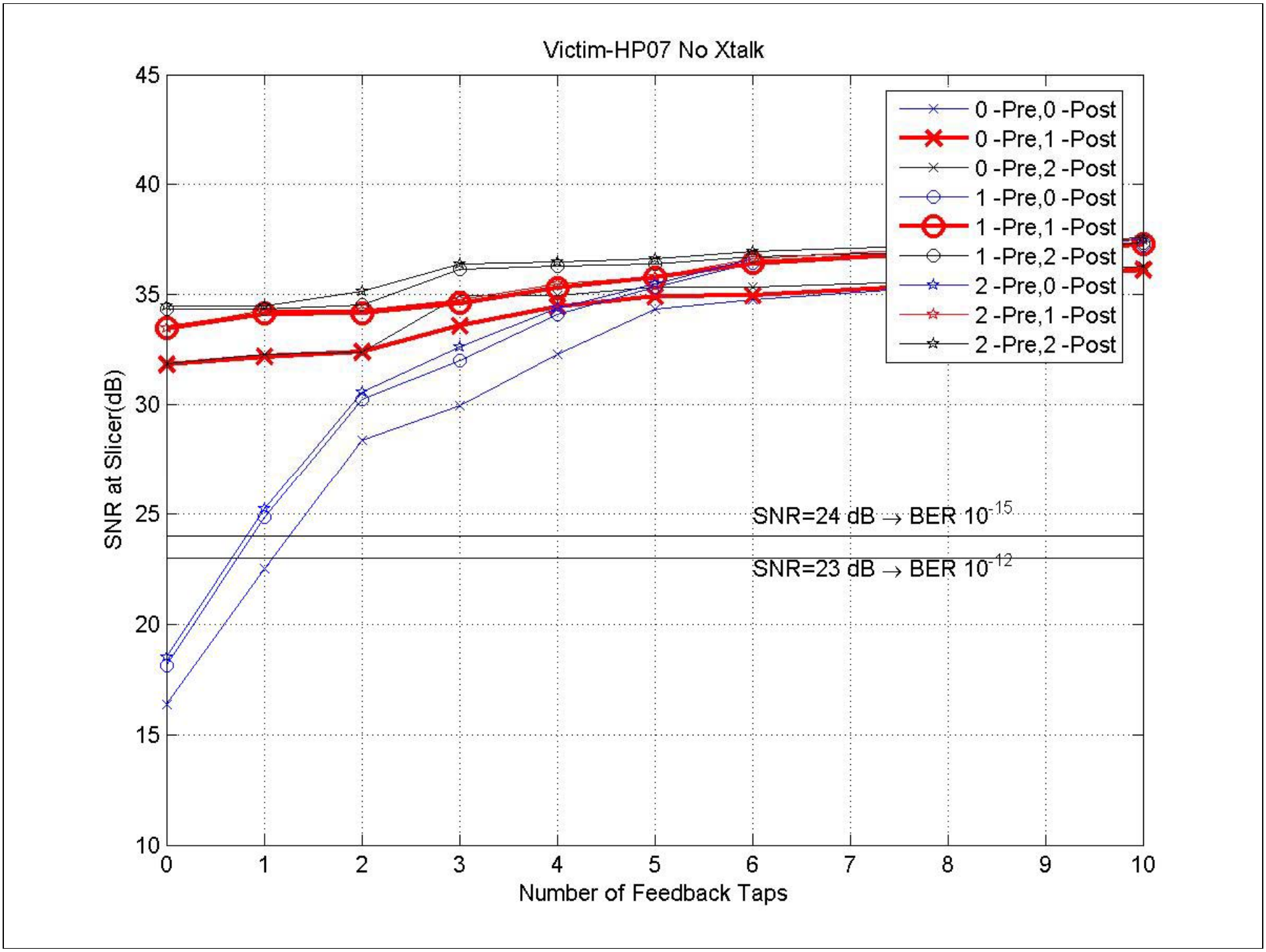
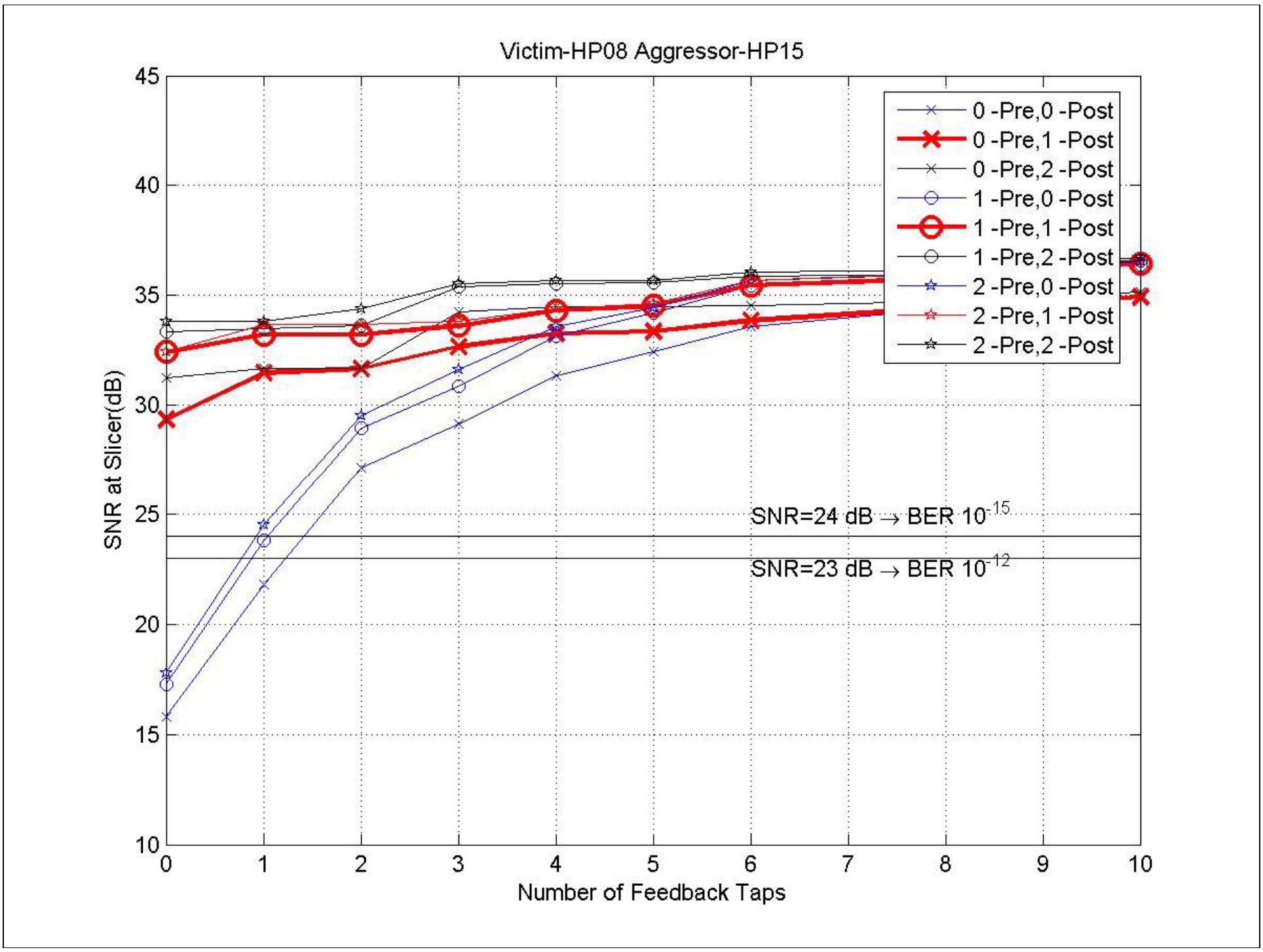
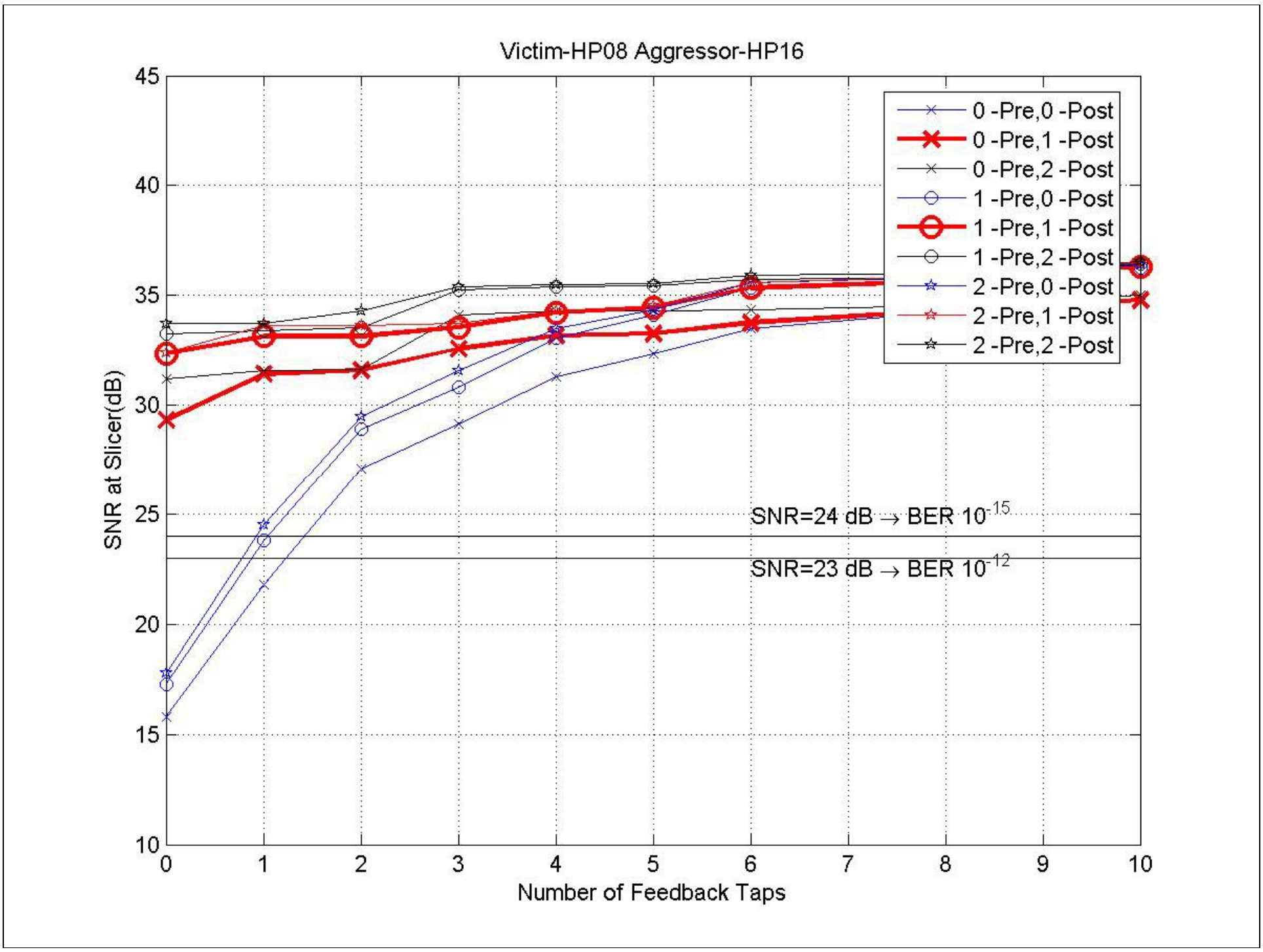
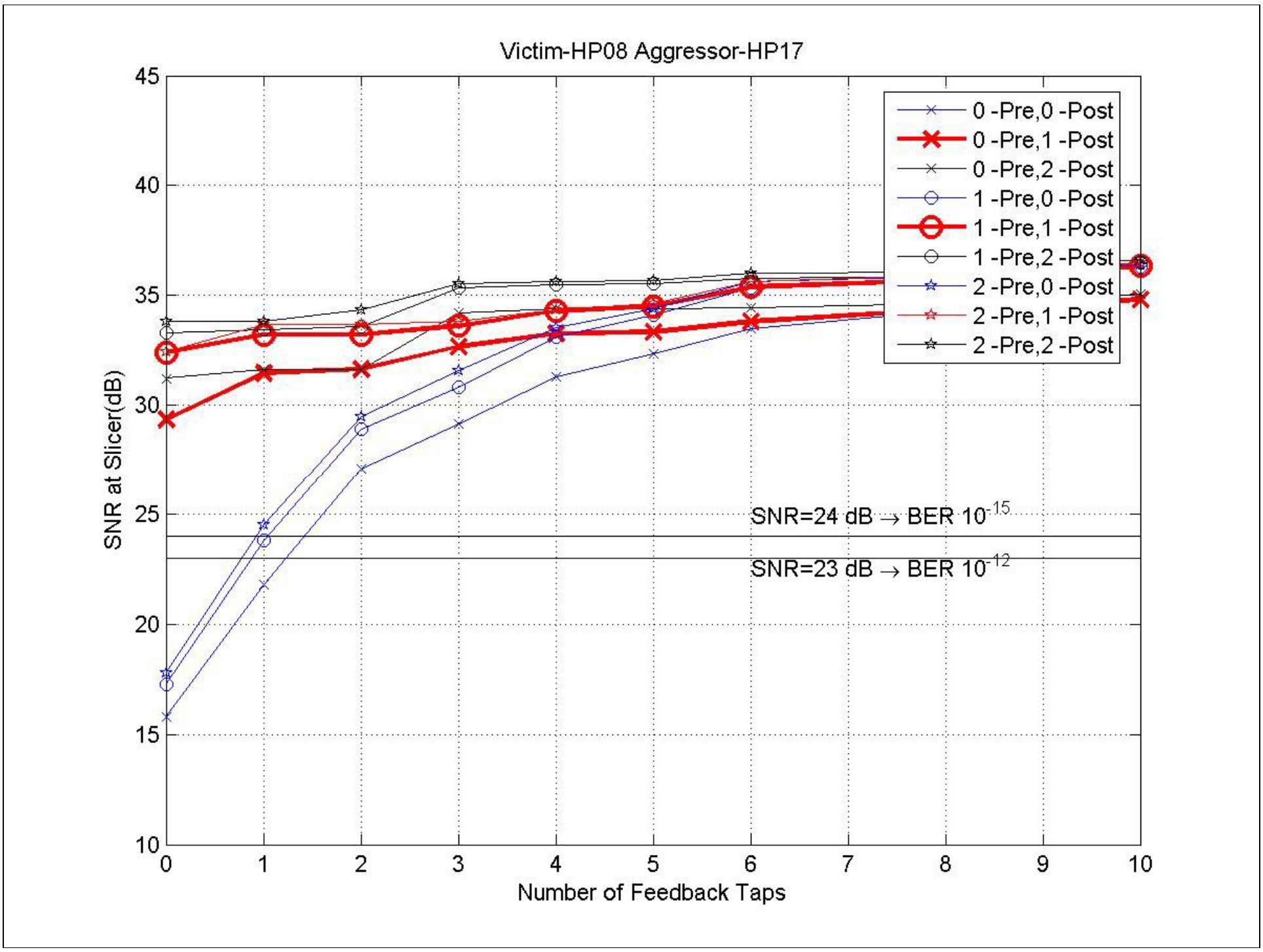
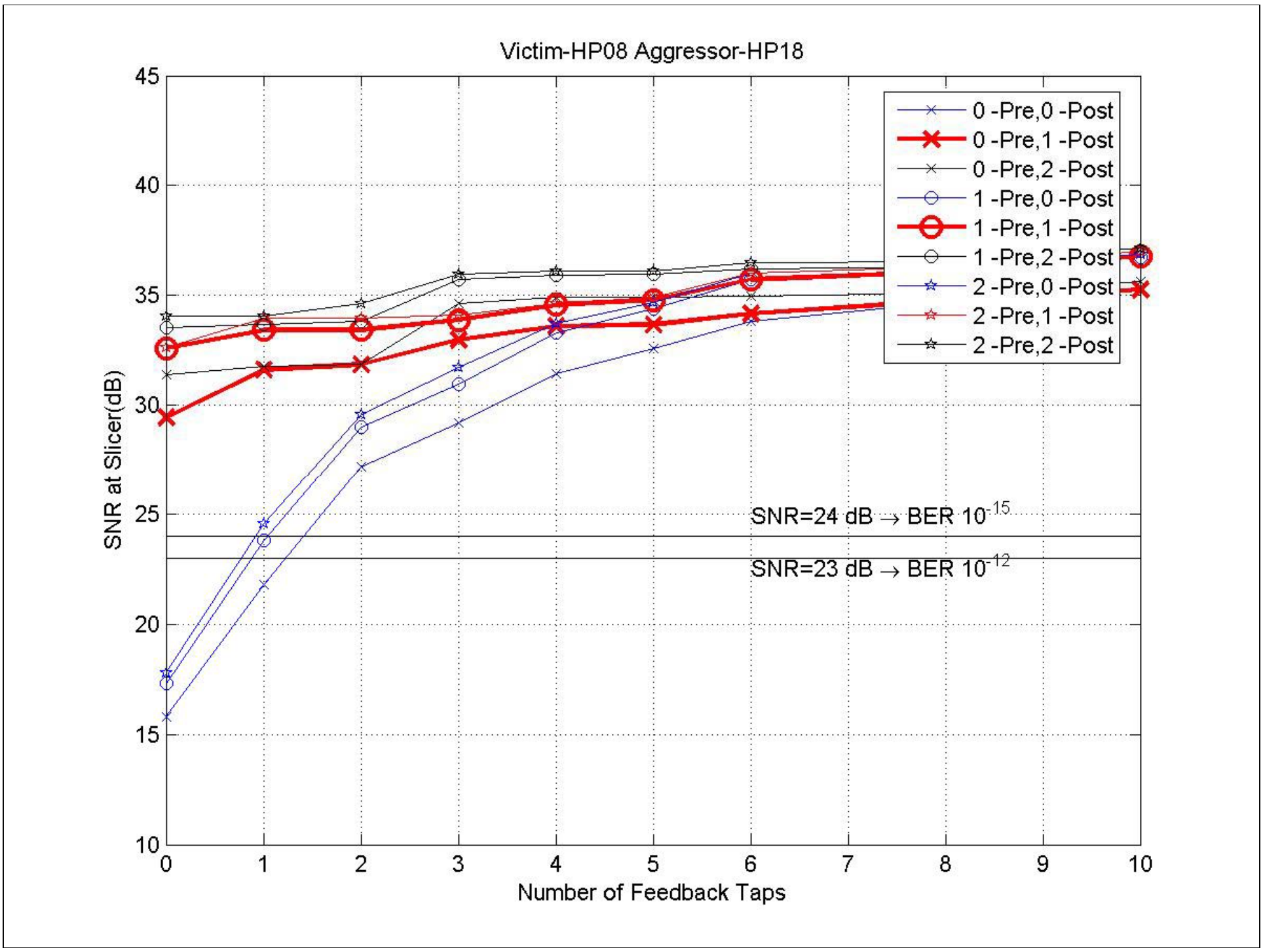

Victim-HP07 Aggressor-HP19
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

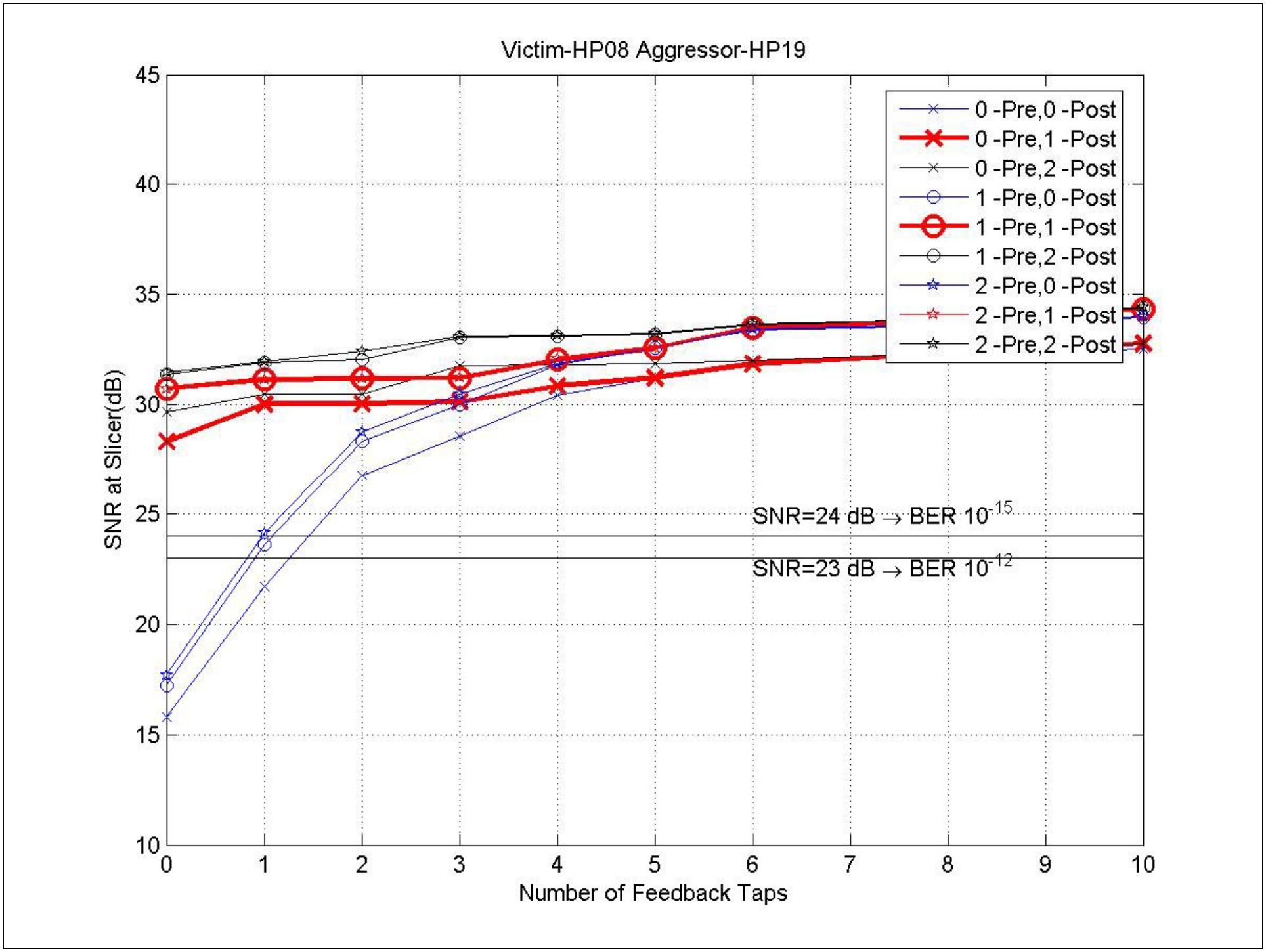

Victim-HP07 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

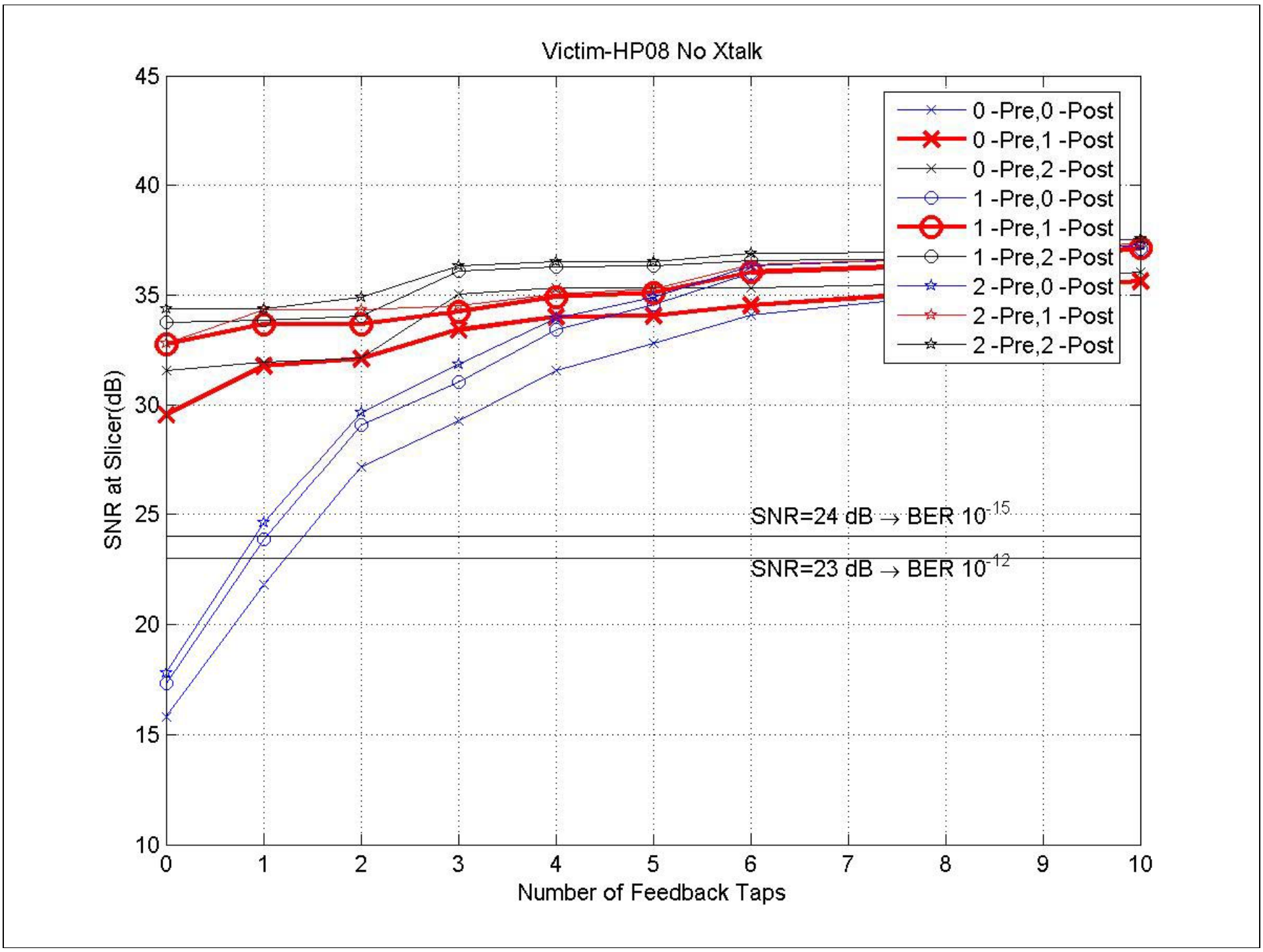

Victim-HP08 Aggressor-HP15
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

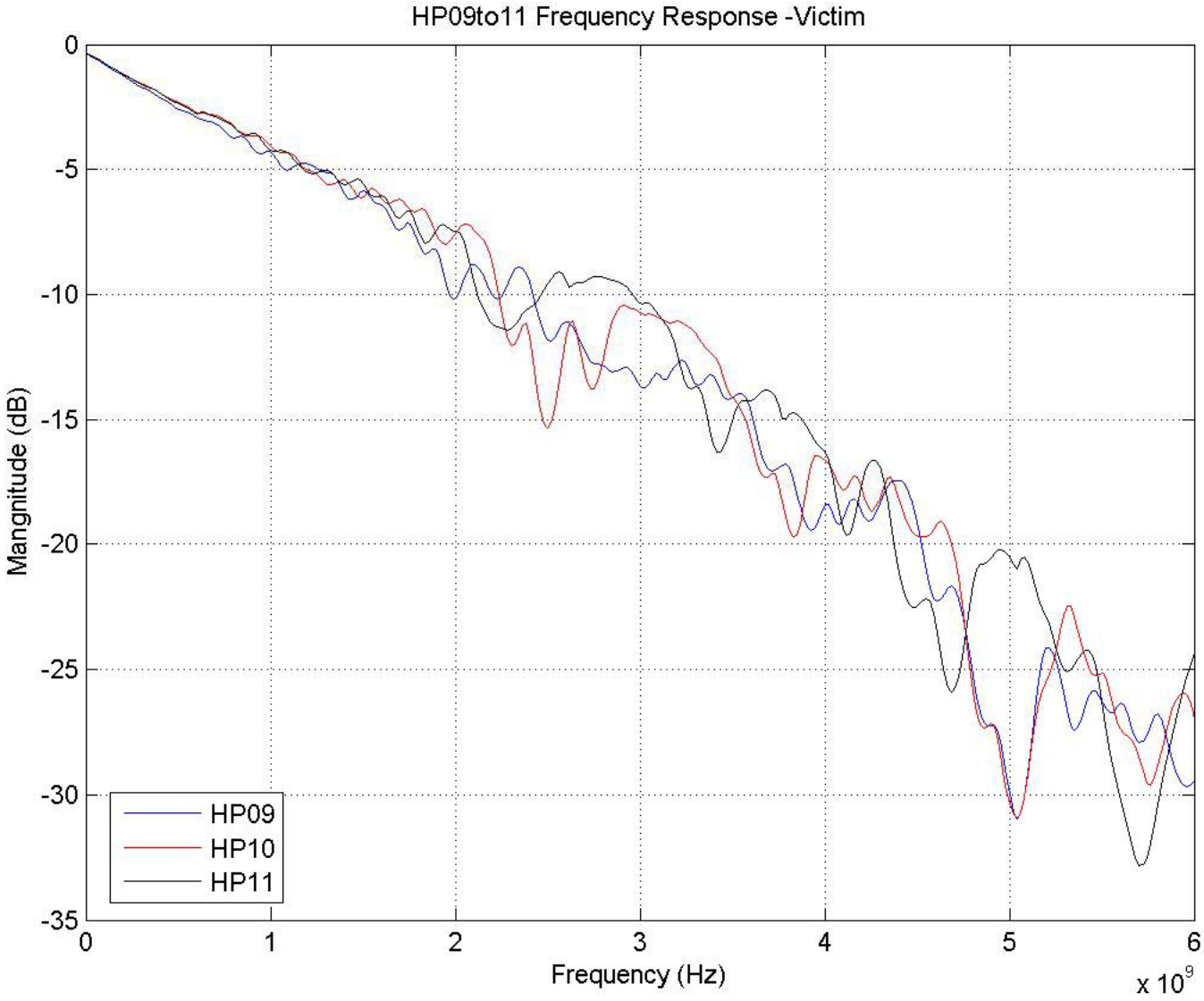

Victim-HP08 Aggressor-HP16
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

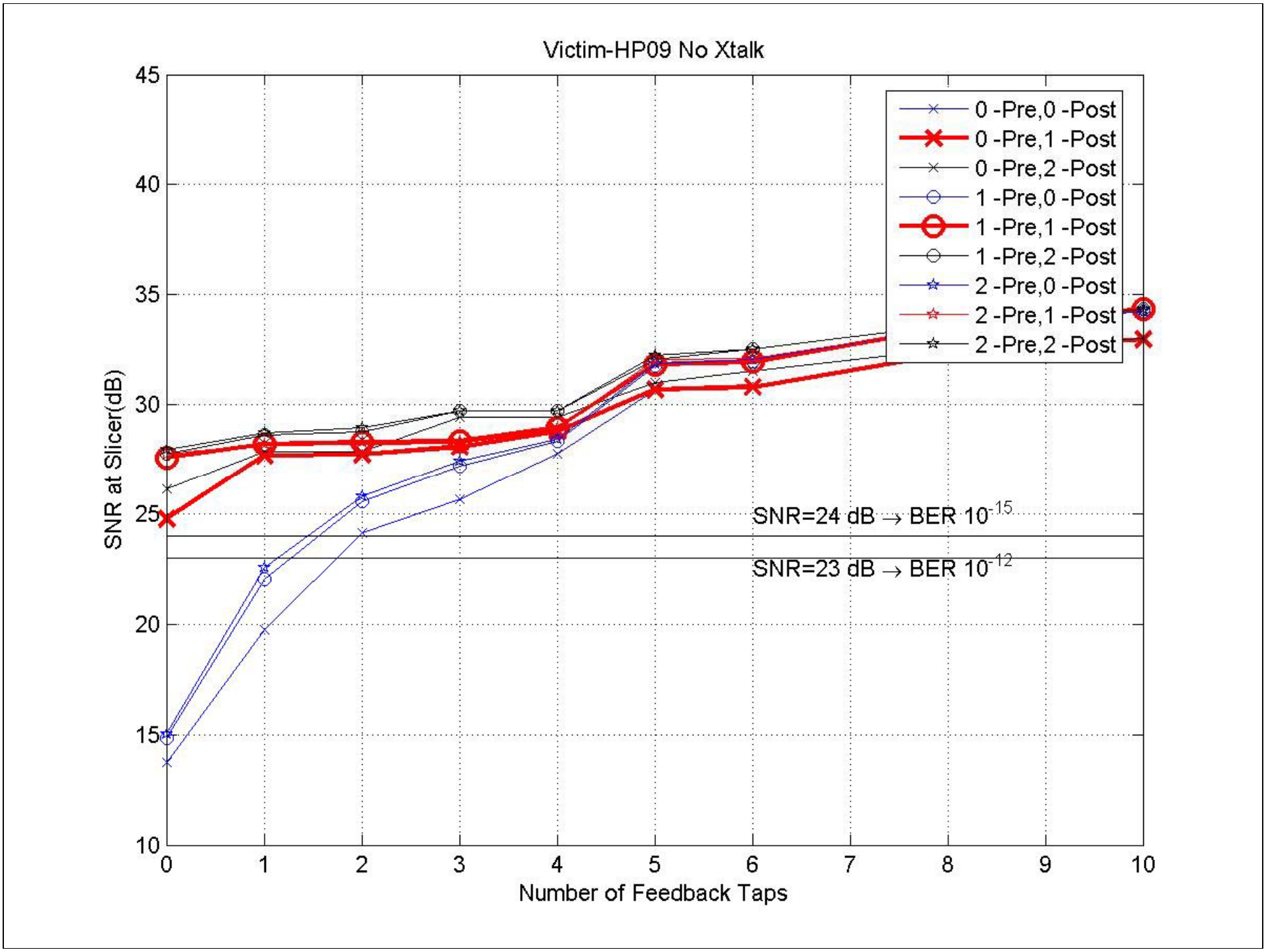

Victim-HP08 Aggressor-HP17
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

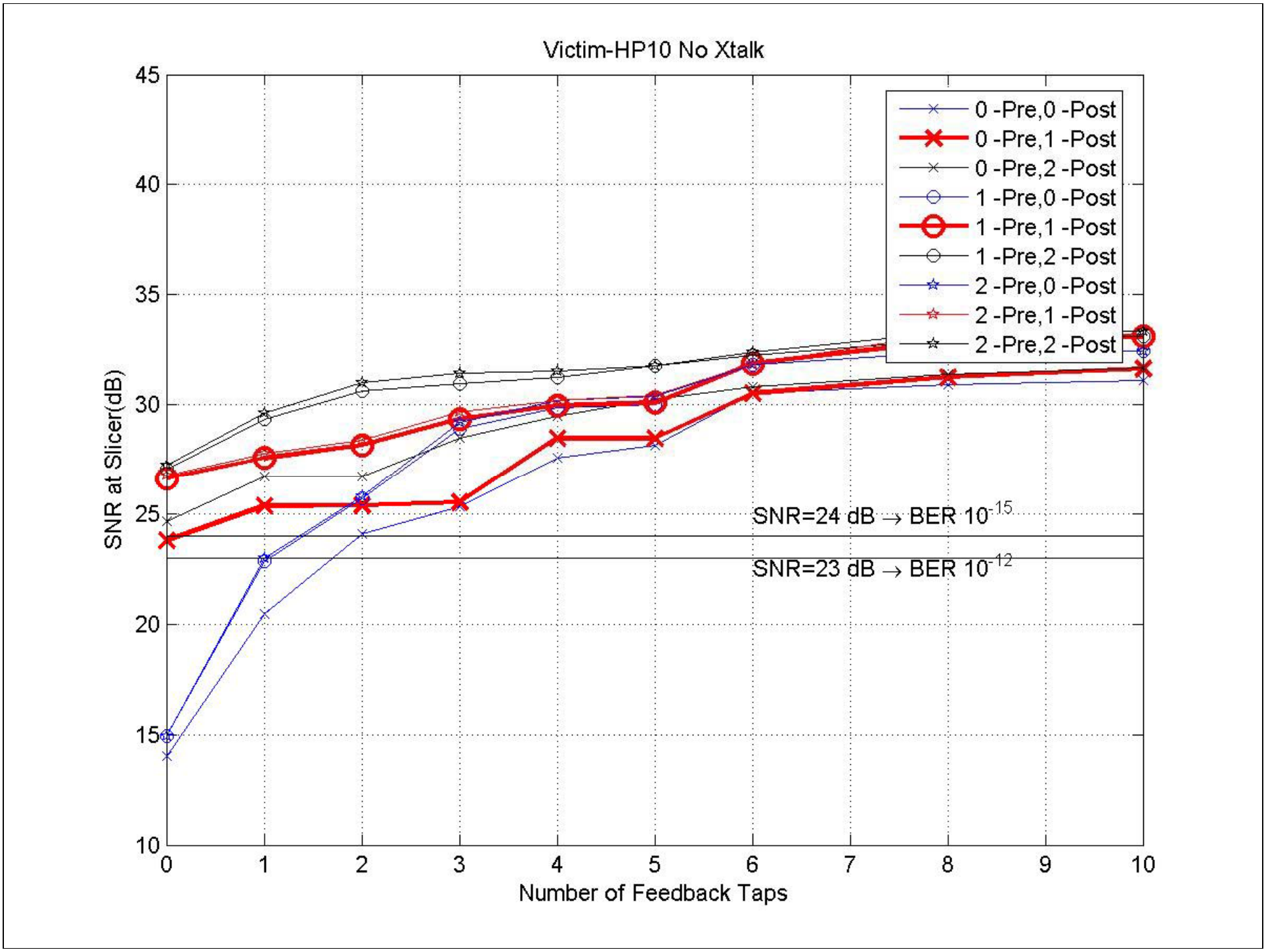

Victim-HP08 Aggressor-HP18
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

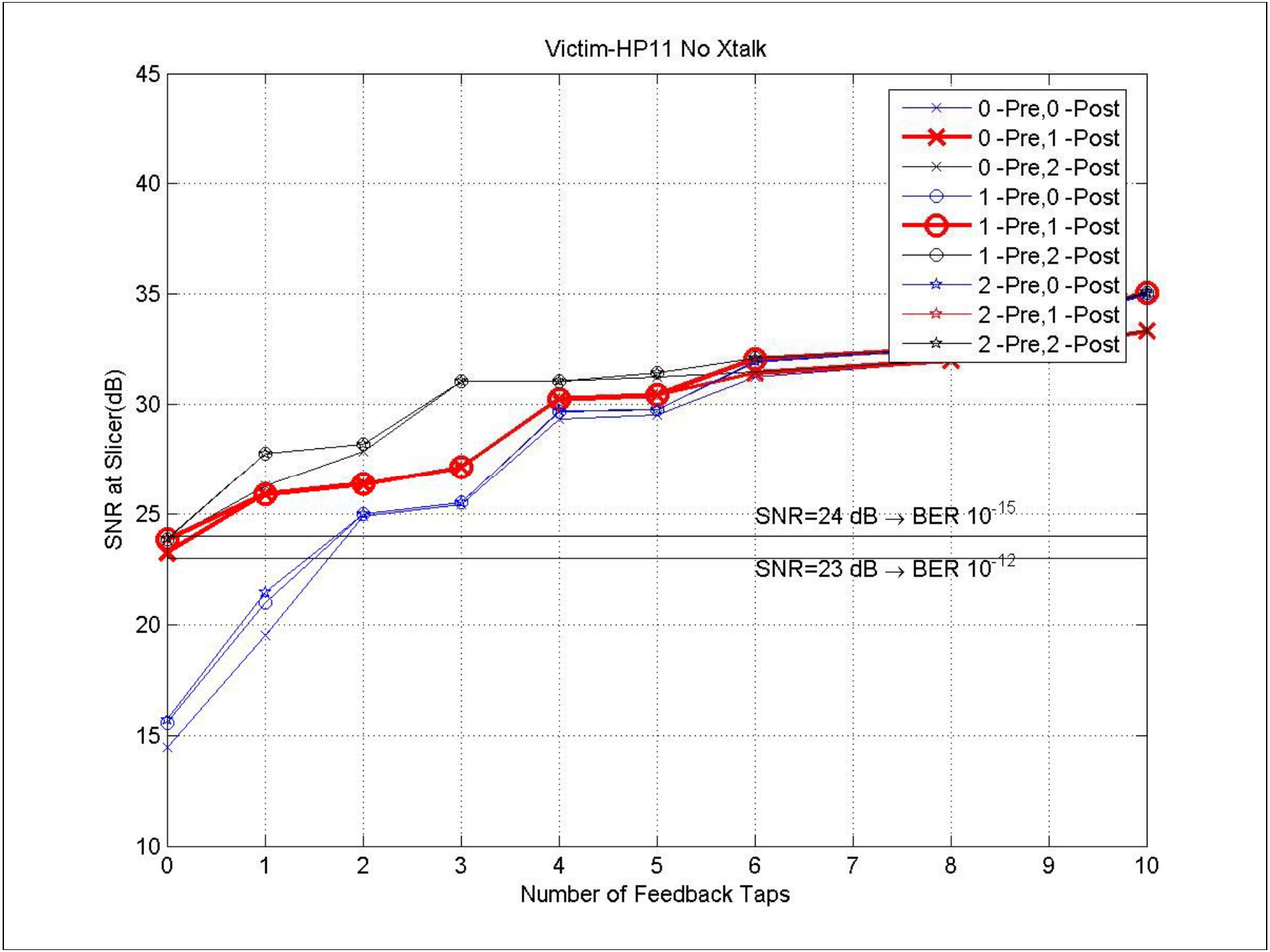

Victim-HP08 Aggressor-HP19
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

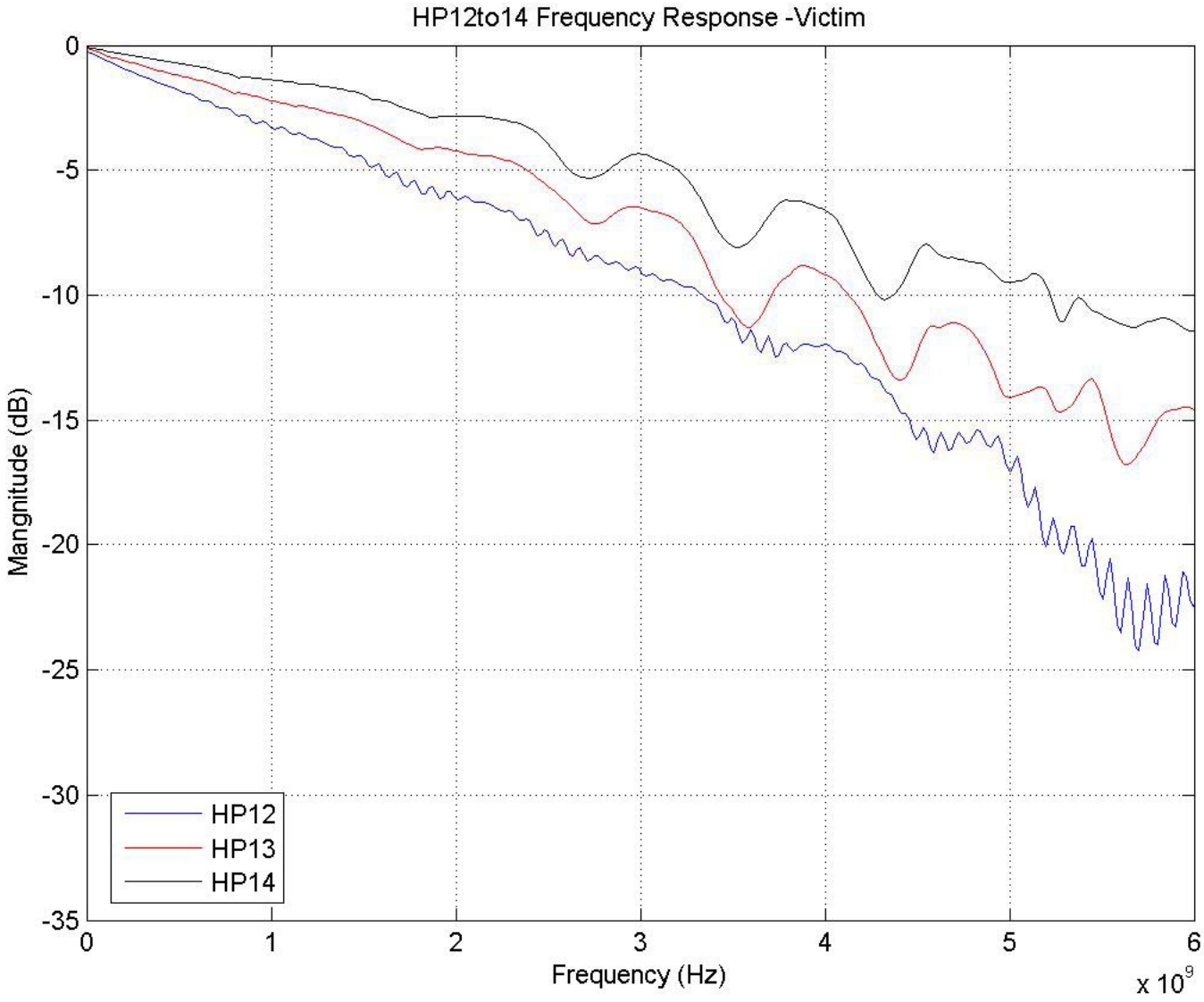

Victim-HP08 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

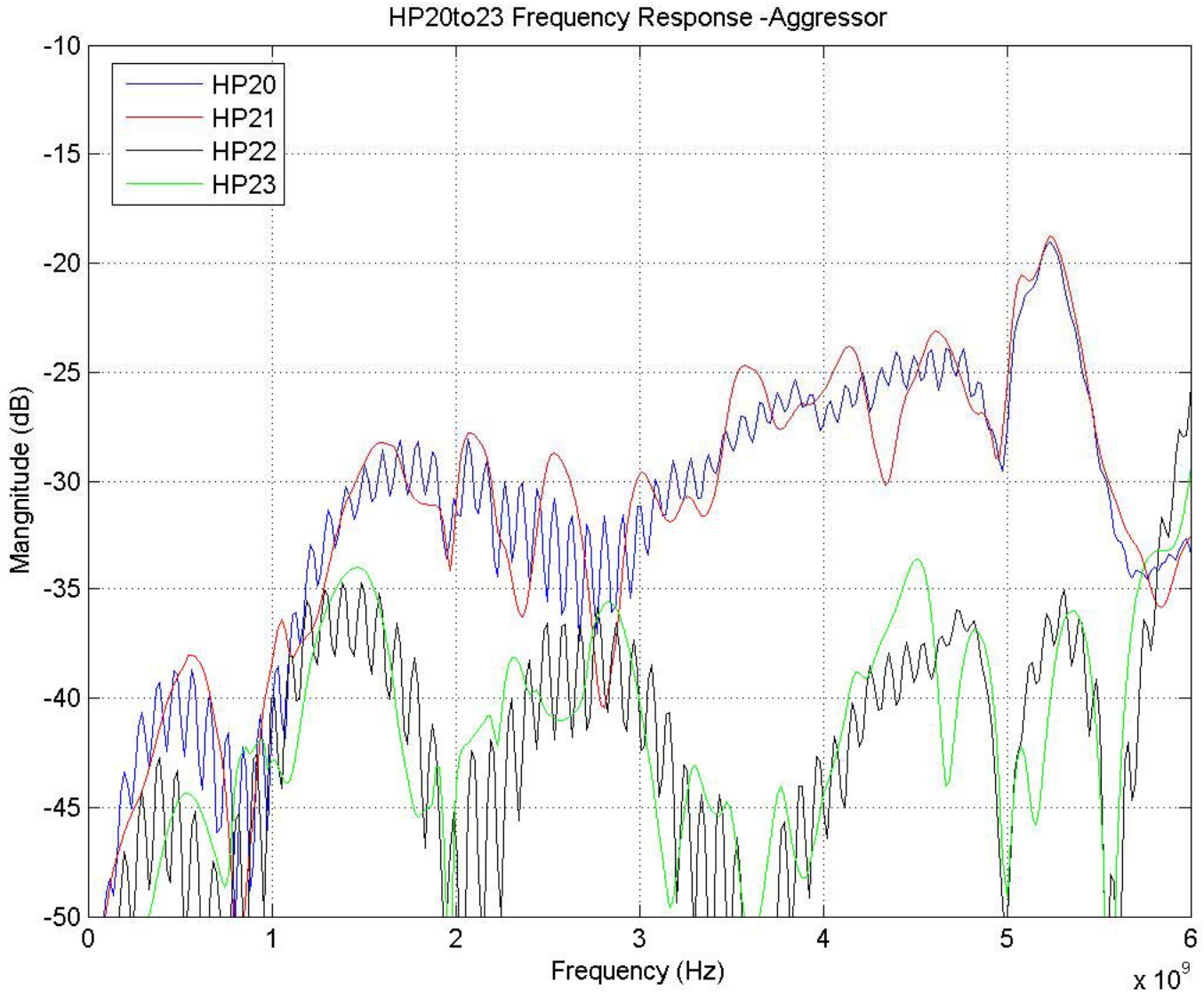

HP09to11 Frequency Response -Victim
Mangnitude (dB)
0
-5
-10
-15
-20
-25
-30
-35
0
1
2
3
4
5
6
Frequency (Hz)
x 10^9
HP09
HP10
HP11

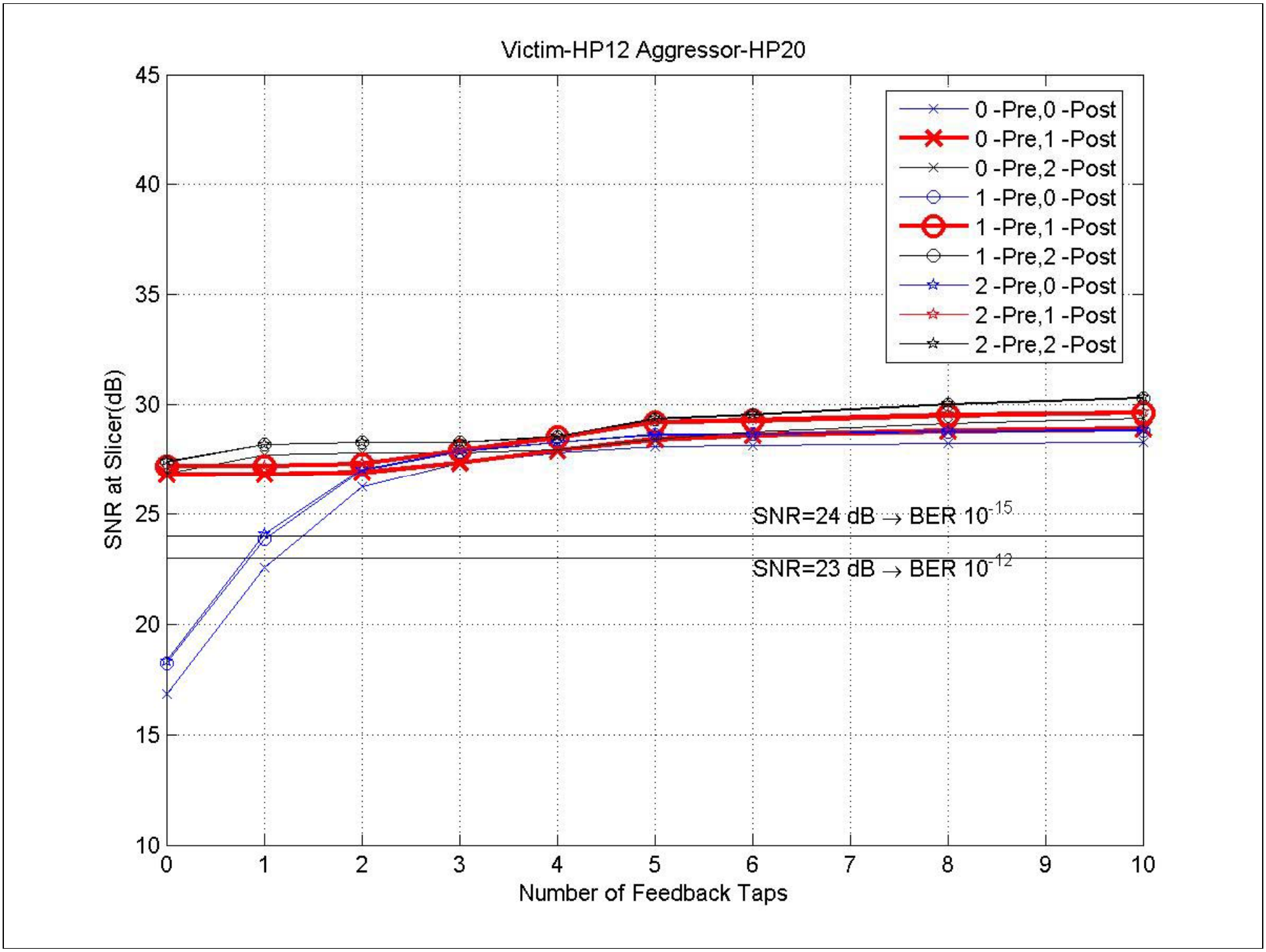

Victim-HP09 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

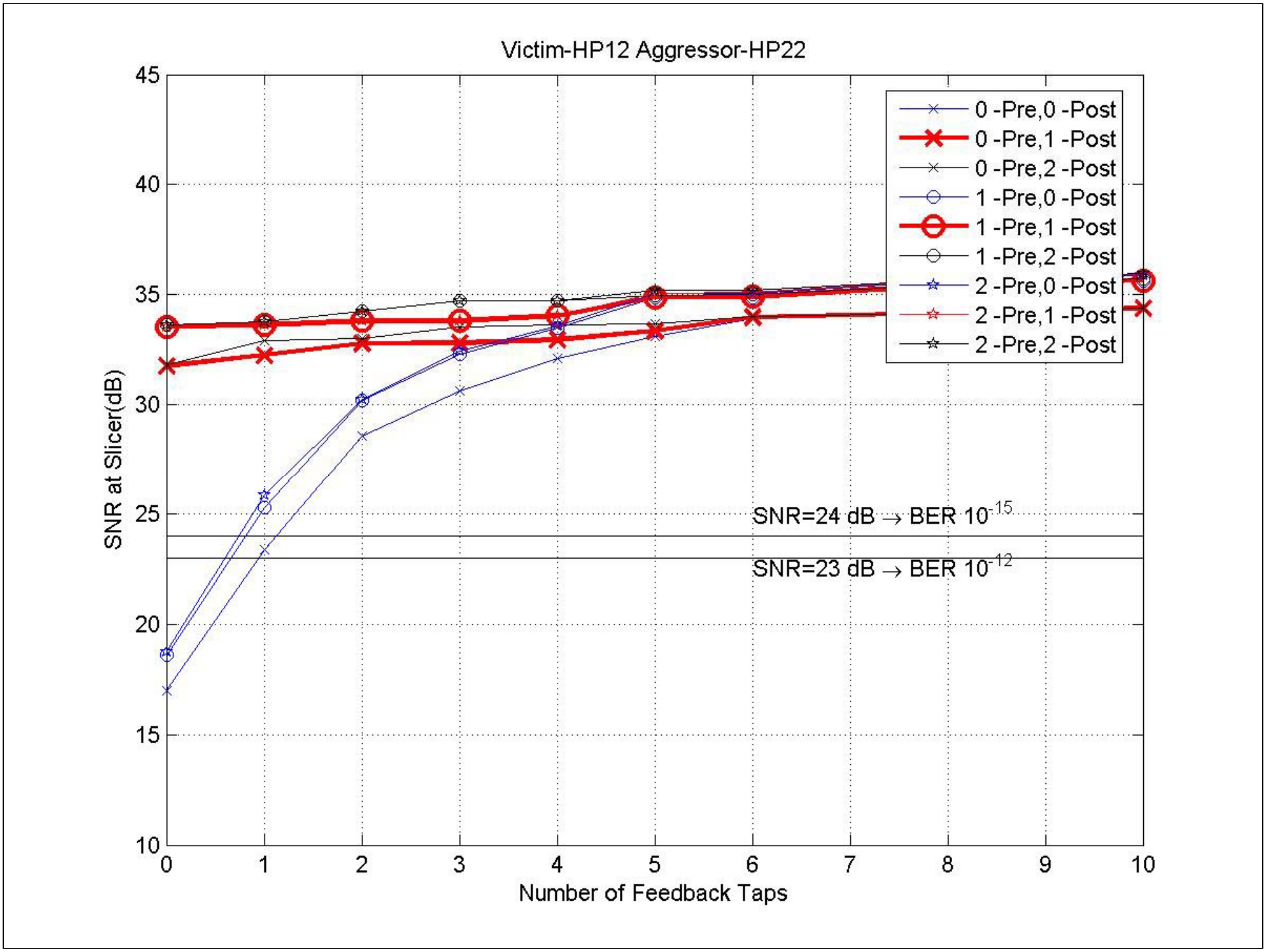

Victim-HP10 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

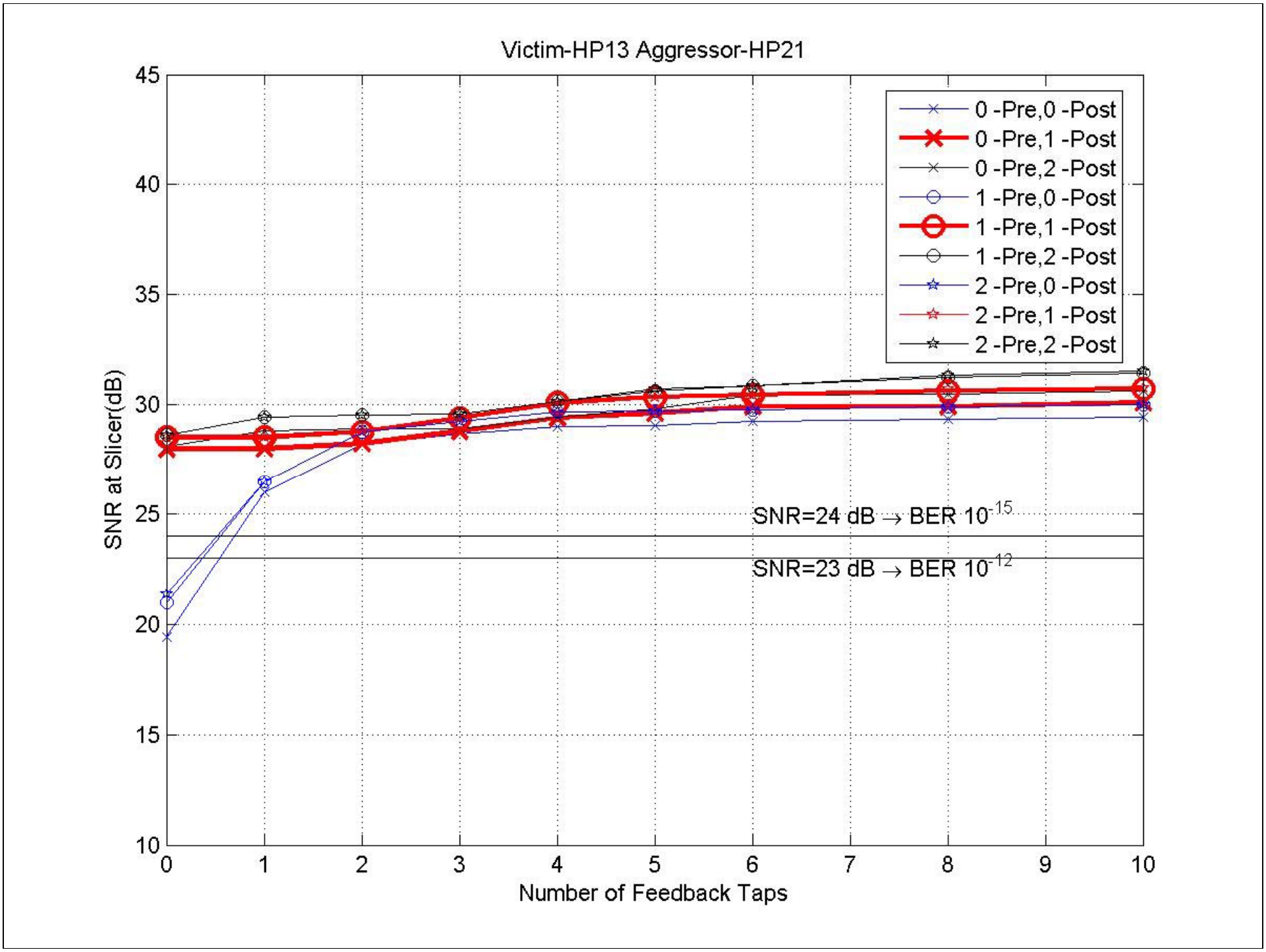

Victim-HP11 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

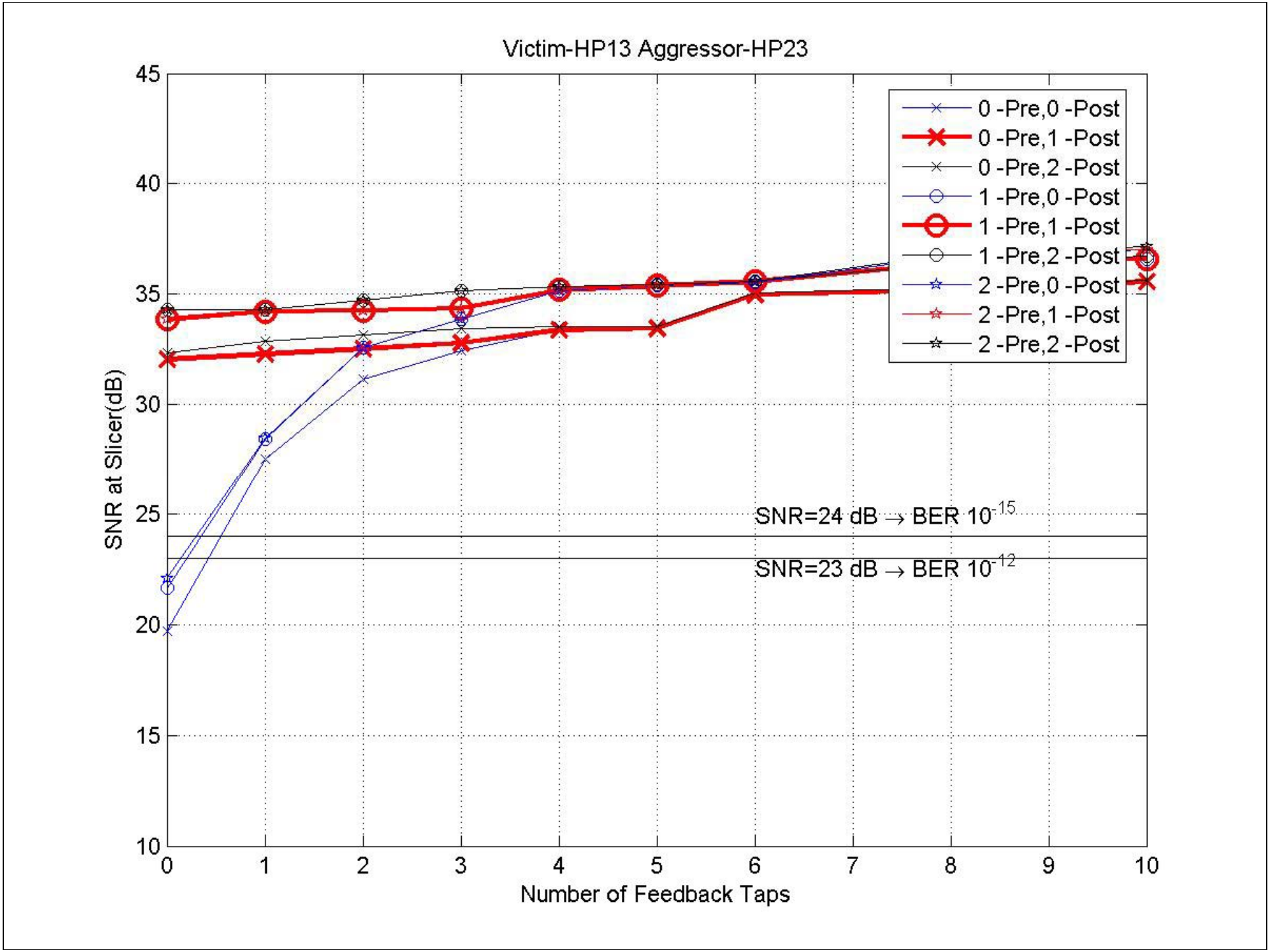

HP12to14 Frequency Response -Victim
Mangnitude (dB)
0
-5
-10
-15
-20
-25
-30
-35
0
1
2
3
4
5
6
Frequency (Hz)
x 10^9
HP12
HP13
HP14

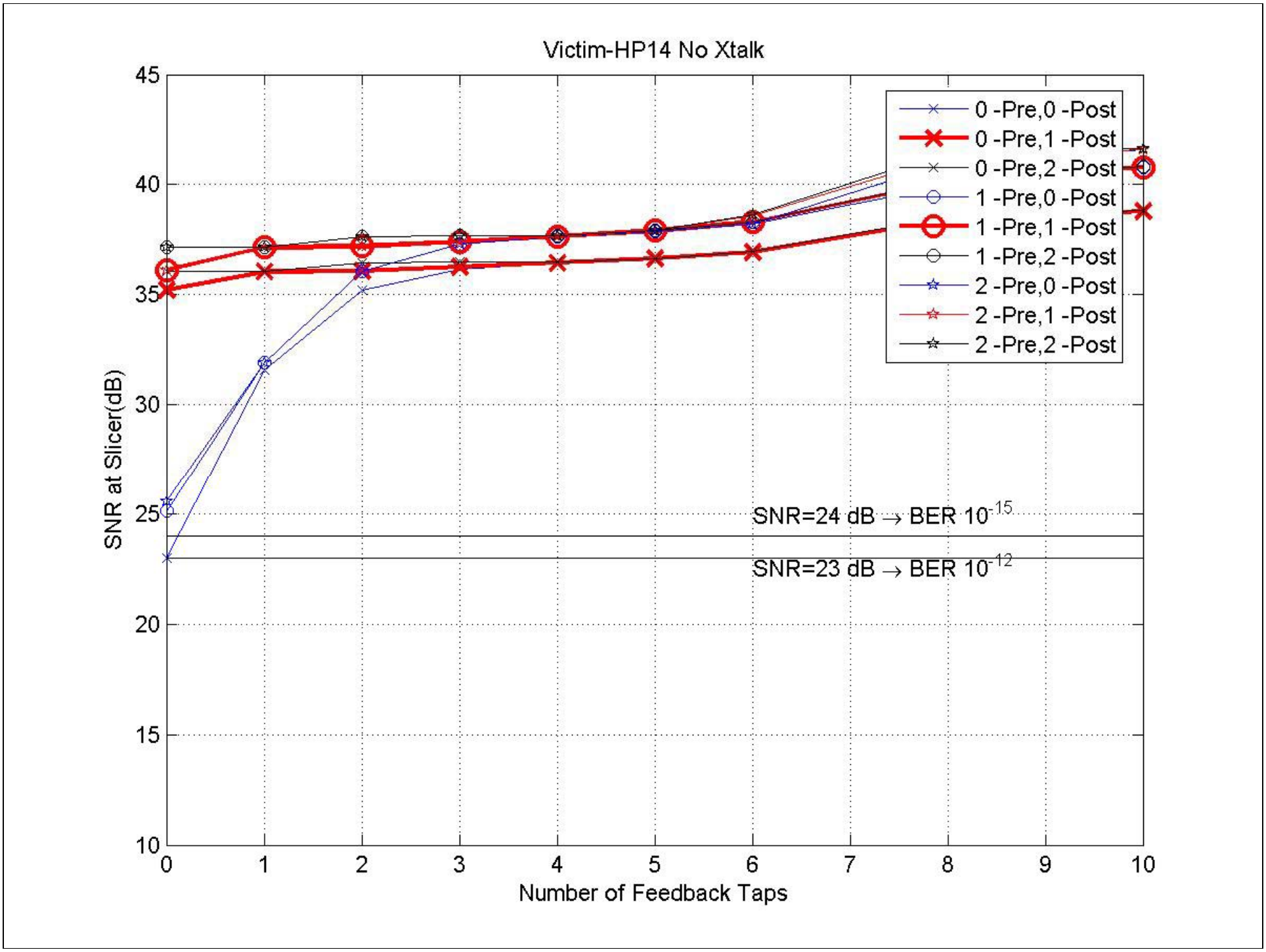

HP20to23 Frequency Response -Aggressor
HP20
HP21
HP22
HP23
Mangnitude (dB)
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
1
2
3
4
5
6
Frequency (Hz)
x 10^9

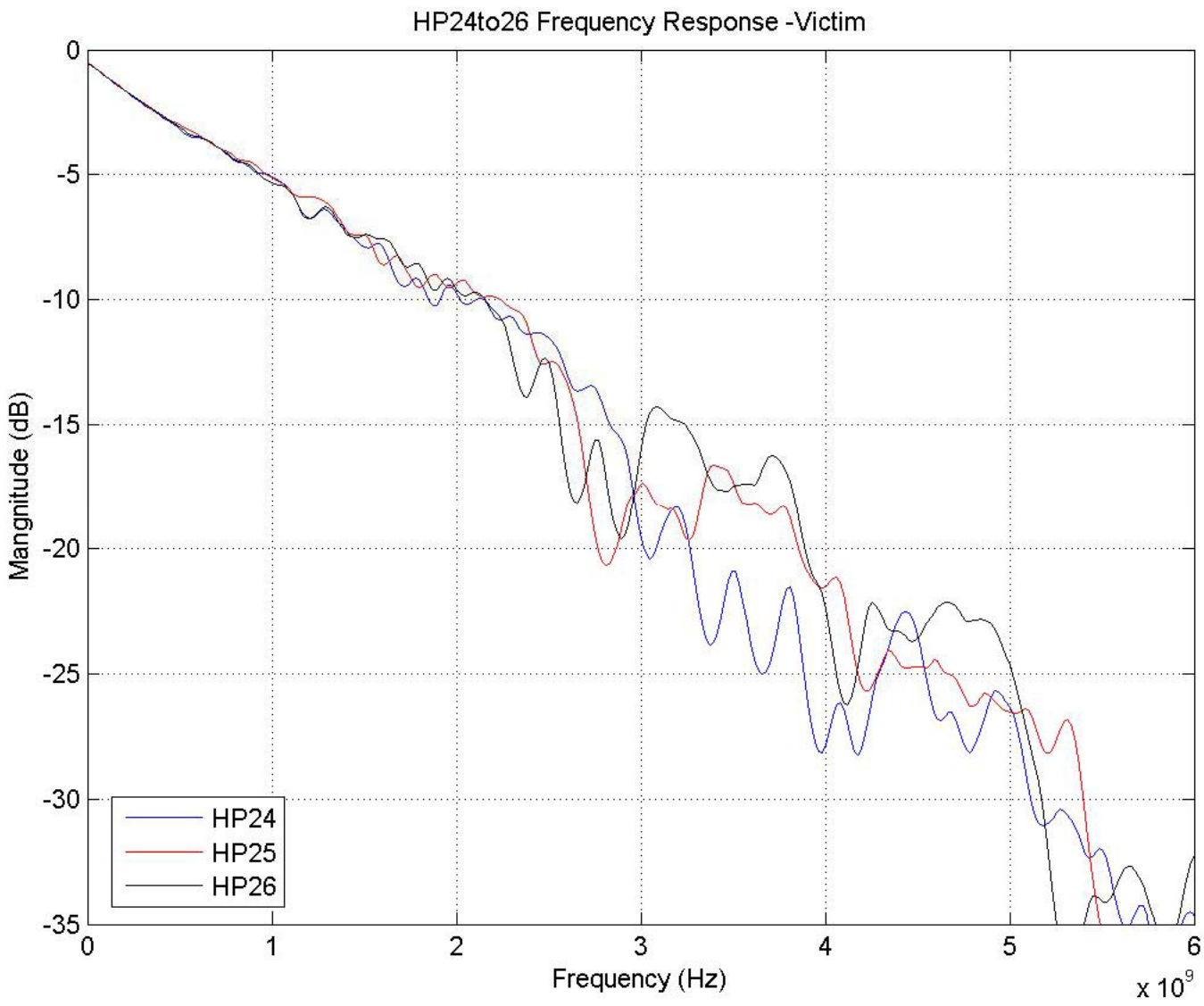

Victim-HP12 Aggressor-HP20
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

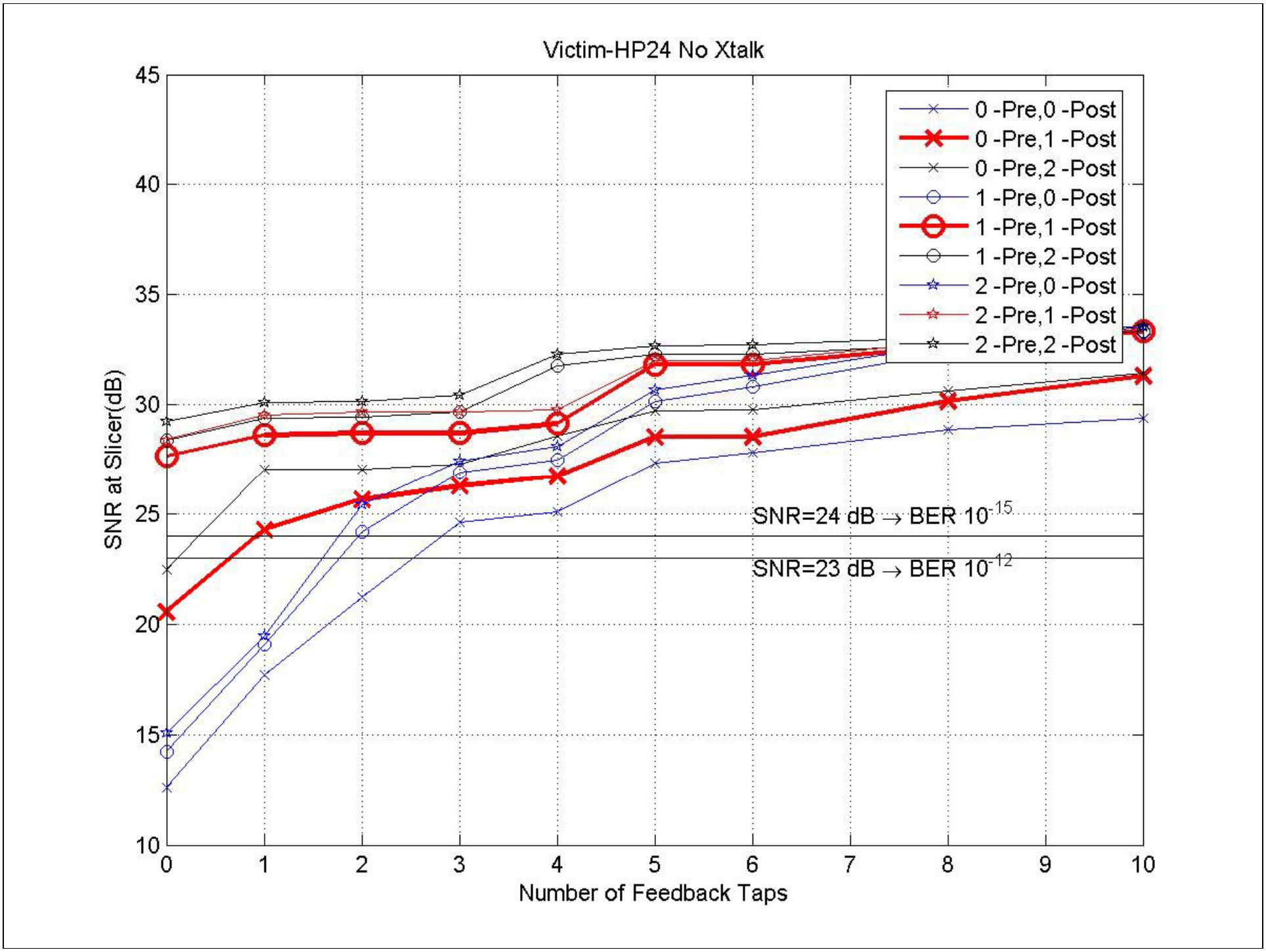

Victim-HP12 Aggressor-HP22
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

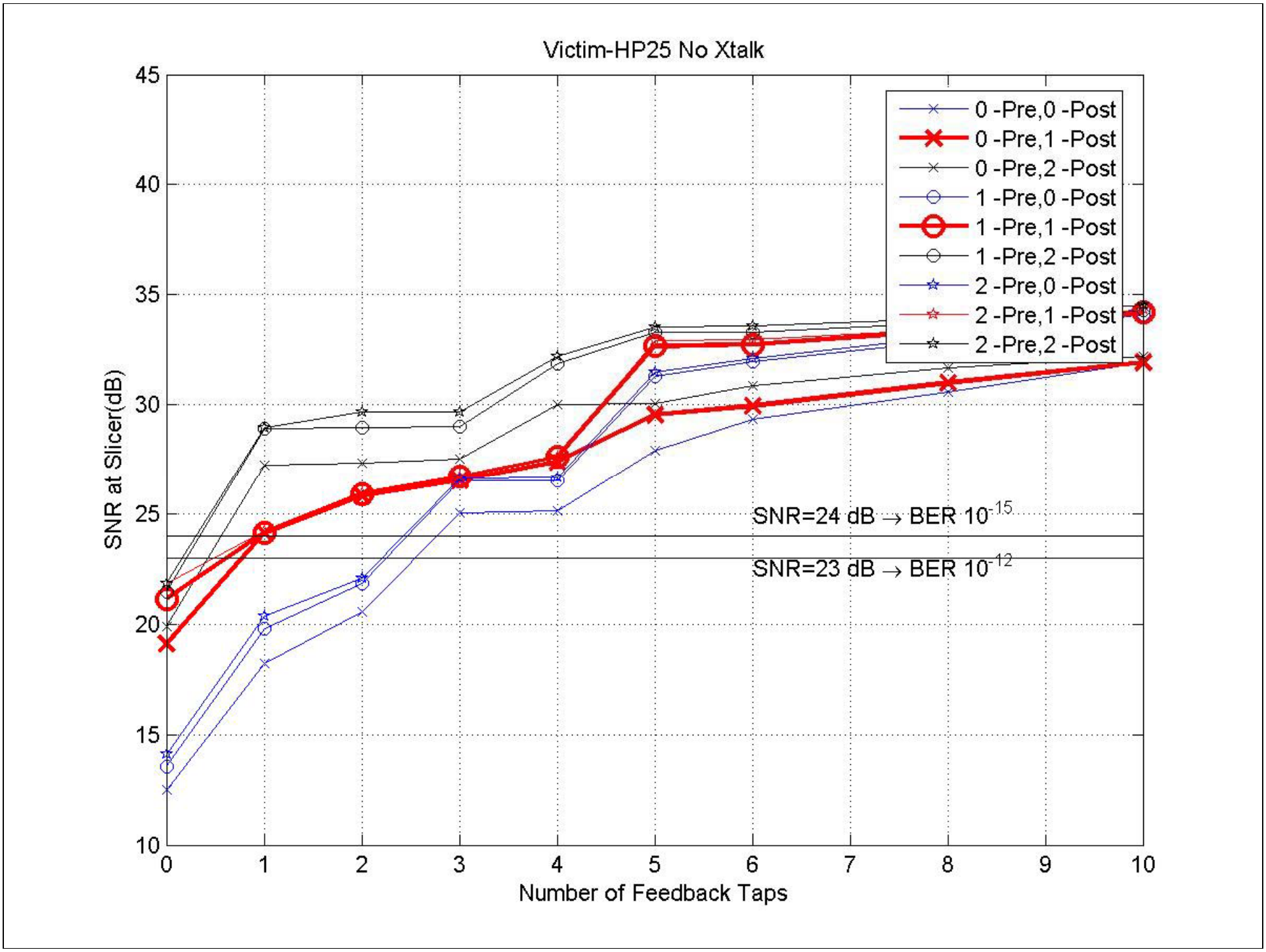

Victim-HP13 Aggressor-HP21
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

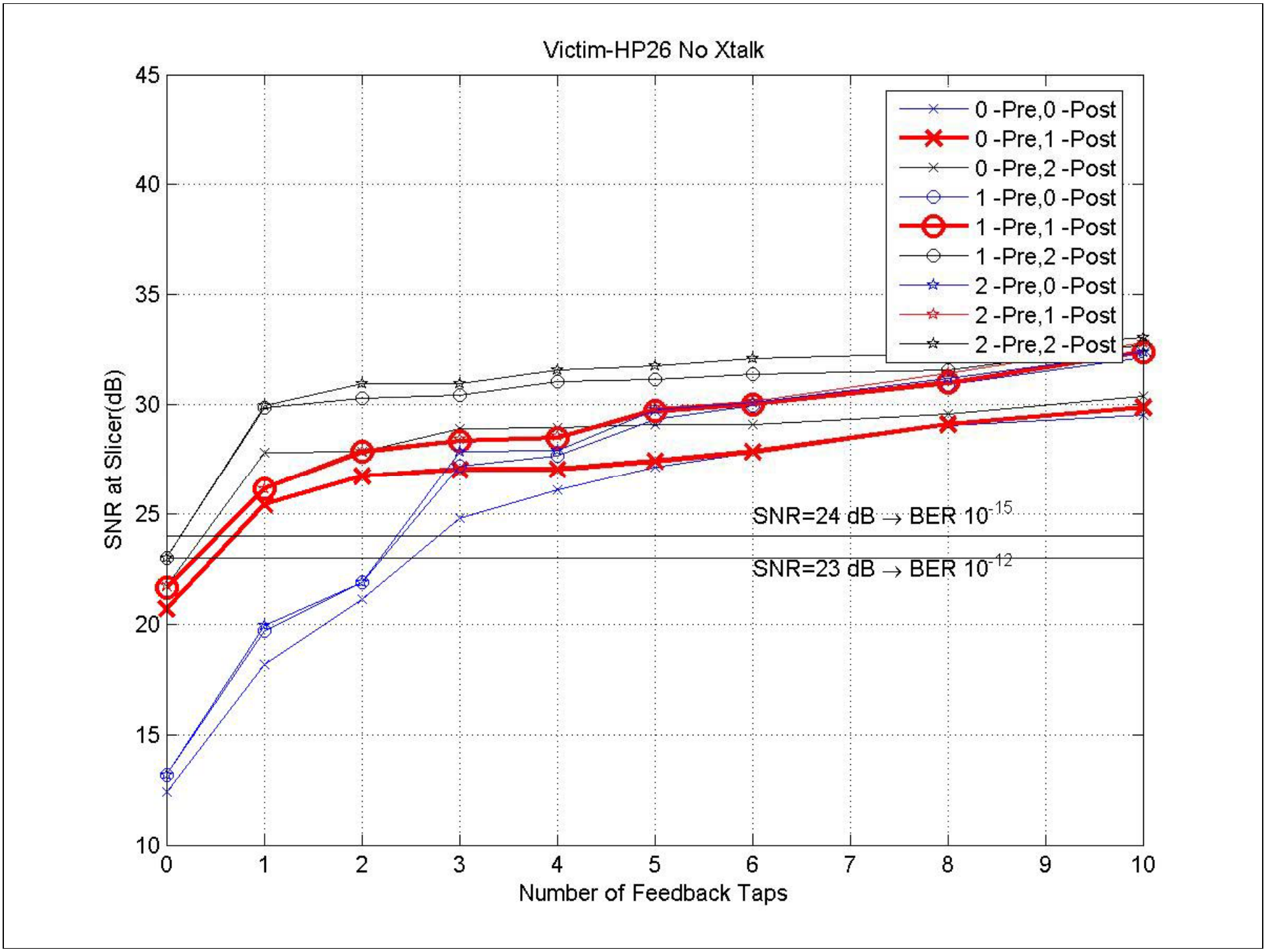

Victim-HP13 Aggressor-HP23
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10


Victim-HP14 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10


HP24to26 Frequency Response -Victim
Mangnitude (dB)
0
-5
-10
-15
-20
-25
-30
-35
0
1
2
3
4
5
6
Frequency (Hz)
x 10^9
HP24
HP25
HP26

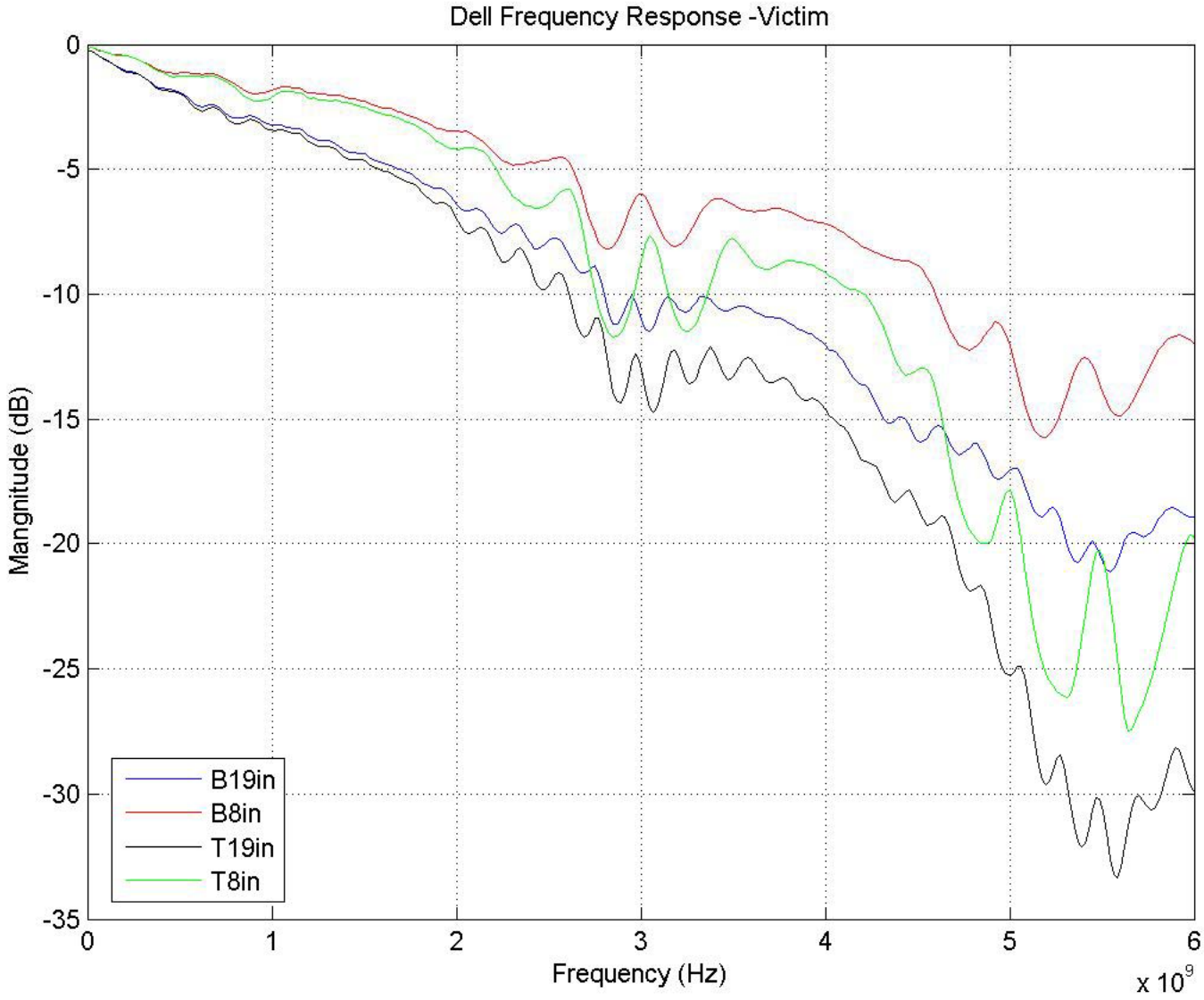

Victim-HP24 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

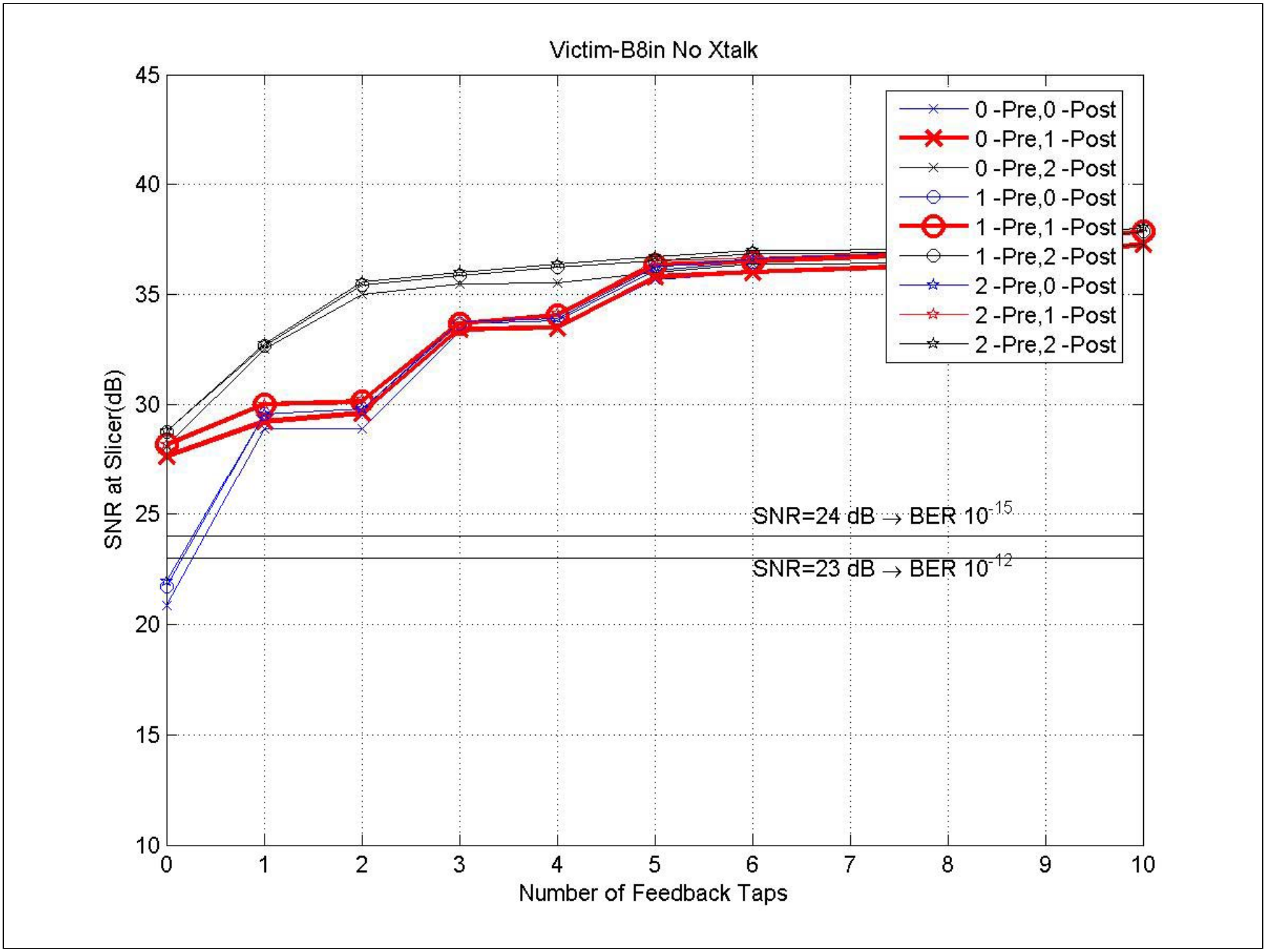

Victim-HP25 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

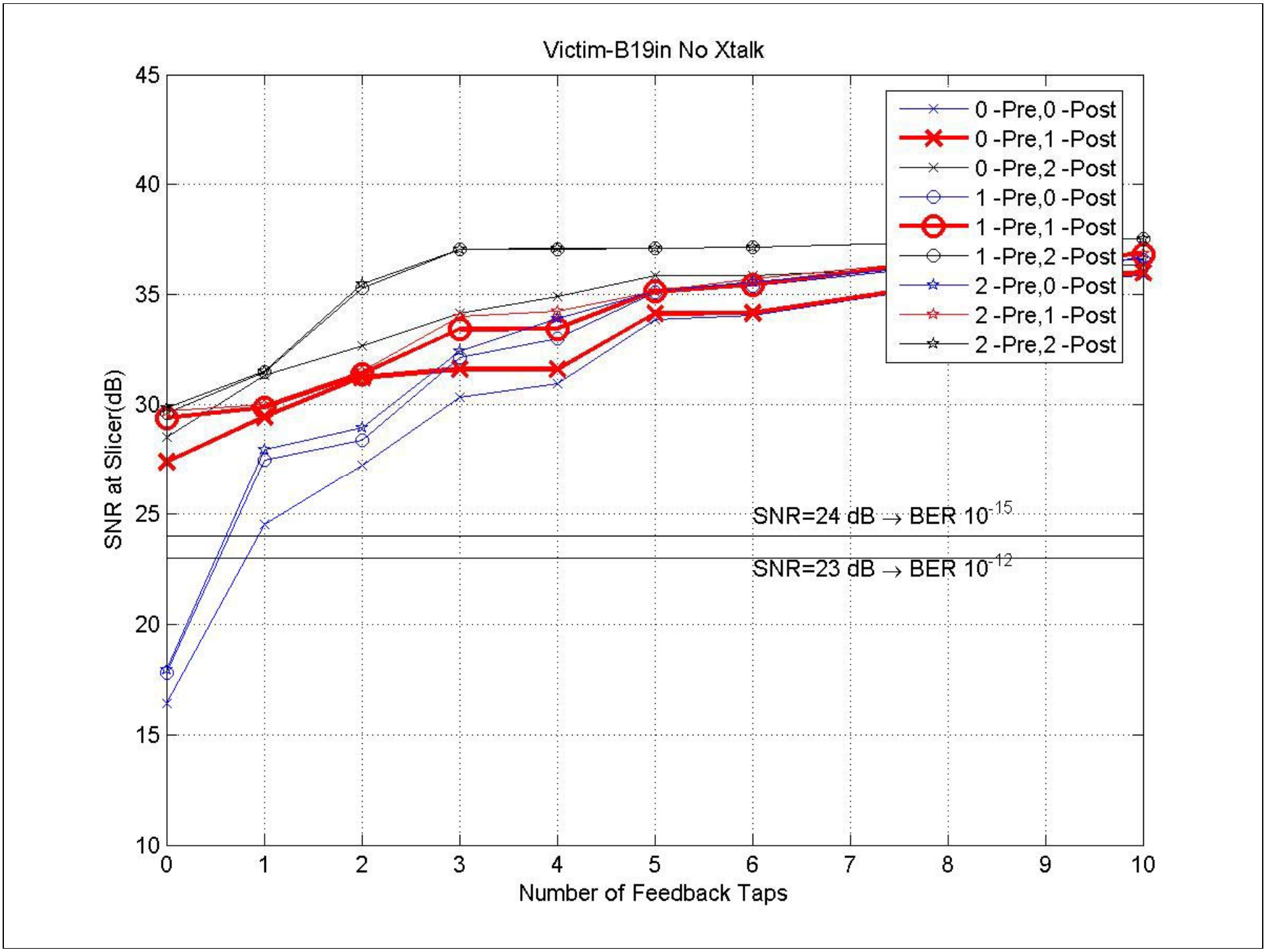

Victim-HP26 No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10

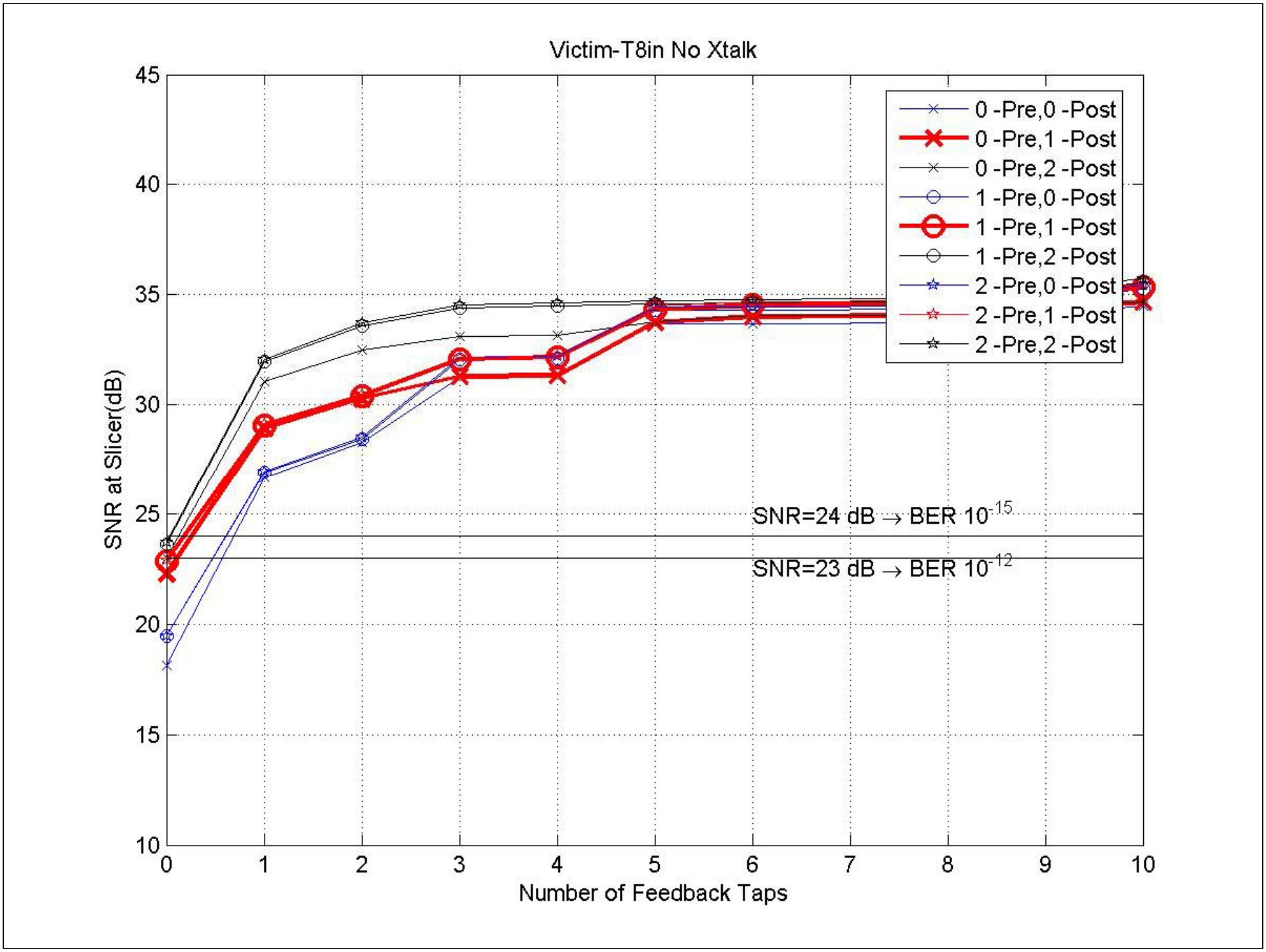
Dell Backplanes

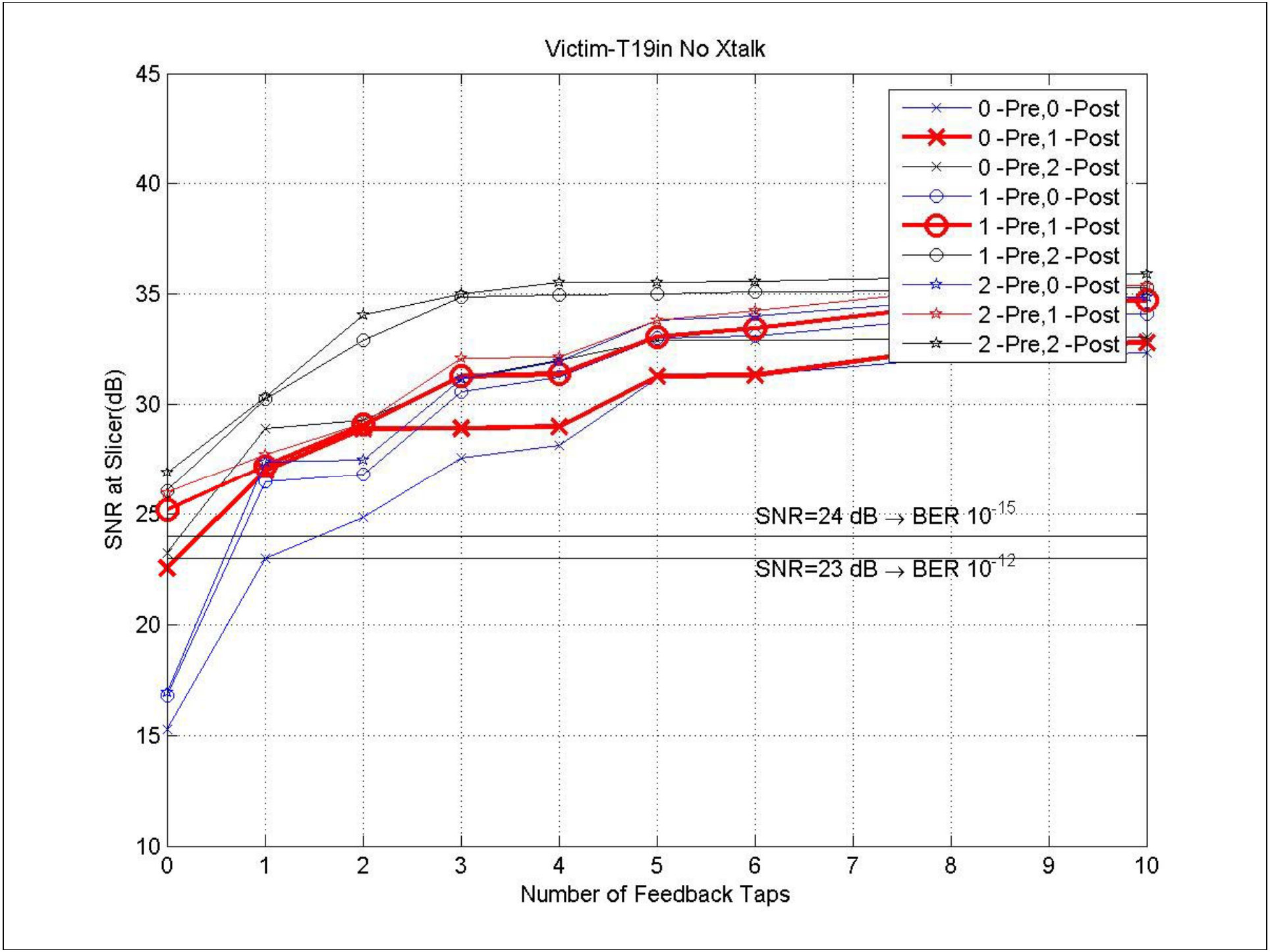
LSI LOGIC


Dell Frequency Response -Victim
Mangnitude (dB)
0
-5
-10
-15
-20
-25
-30
-35
0
1
2
3
4
5
6
Frequency (Hz)
x 10^9
B19in
B8in
T19in
T8in


Victim-B8in No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10


Victim-B19in No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10


Victim-T8in No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10


Victim-T19in No Xtalk
SNR at Slicer(dB)
Number of Feedback Taps
0 -Pre,0 -Post
0 -Pre,1 -Post
0 -Pre,2 -Post
1 -Pre,0 -Post
1 -Pre,1 -Post
1 -Pre,2 -Post
2 -Pre,0 -Post
2 -Pre,1 -Post
2 -Pre,2 -Post
SNR=24 dB → BER 10^-15
SNR=23 dB → BER 10^-12
45
40
35
30
25
20
15
10
0
1
2
3
4
5
6
7
8
9
10