Simulations of Duobinary and NRZ Over Selected IEEE Channels (Including Jitter and Crosstalk)

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Outline

- Purpose
- Channels
  - Thru
  - Xtalk
- Description
  - Simulation Parameters
  - Jitter
  - Tools
- Simulation Data
- Conclusion
- Acknowledgement
- Supporting Slides

Purpose

- Analyses of Duobinary with Jitter and Crosstalk Effects have not Previously been Presented
- Time Domain Sims Used because Stat Eye Not Yet available for Duobinary
- NRZ included for Comparison, although a Large Amount of NRZ Analyses, including Stat Eye, have been presented

Channels

- 18 Thru Channels Selected
  - 7 Tyco
  - 2 Molex FR408
    - New Data supplied by Molex
    - Not Part of IEEE set, Used by Permission of Molex
  - 9 Intel
  - Represents top, mid, bottom layers as well as various lengths
- 3 Xtalk Channels Selected
  - Worst Tyco NEXT from Among All Tyco “N1” Cases
  - Worst Molex NEXT from among all Available Molex NEXT Data
  - Worst Case Intel NEXT from among all Intel NEXT Data
  - Worst Case means highest magnitude in the 2.5 GHz to 7.5 GHz region (choice somewhat subjective)

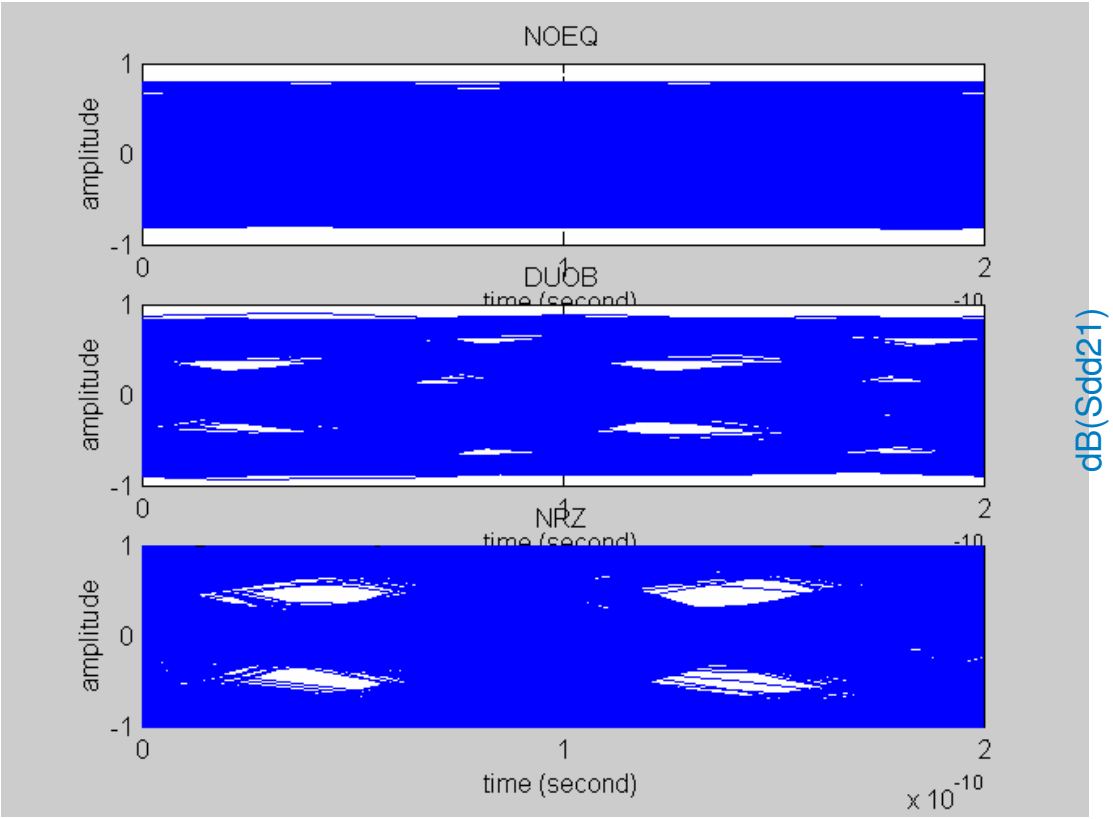
Description

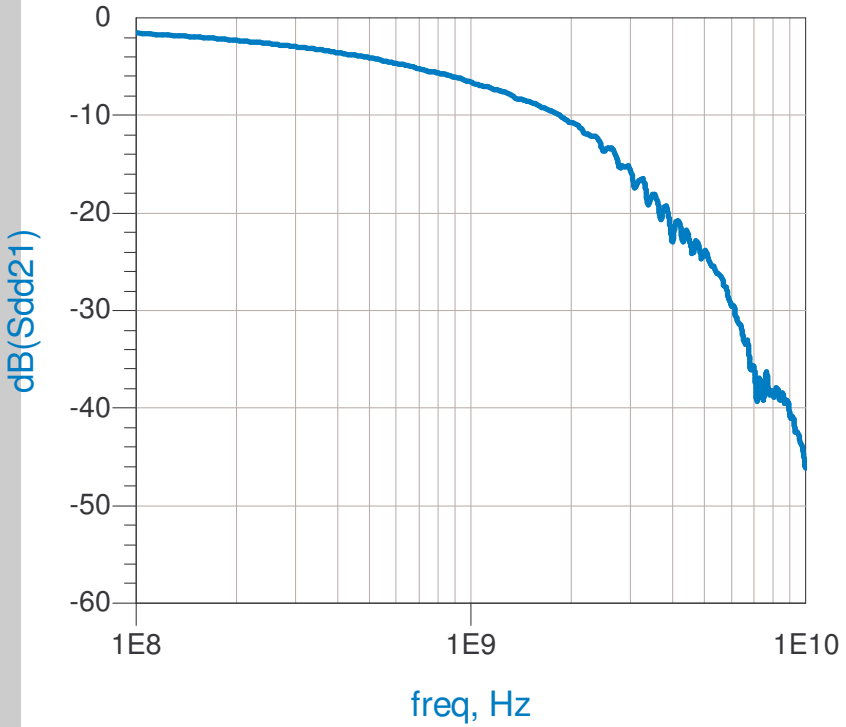
- Simulation Parameters
  - Bit Rate for Signal and Xtalk = 10 Gbps
  - All Equalization (Duo or NRZ) = 3 tap FFE Using LS Optimization over 13 cursors
  - Thru Signal = 2000 bits of PRBS15 with jitter added
  - All Xtalk = 2 Aggressors, randomly phased, random bits (MATLAB rand)
  - Both Thru Signal and Xtalk Filtered at Tx by Single Pole at 7.5 GHz.
  - ESD Cap of 0.4 pf added at Each of 4 Ports
  - Polynomial extrapolation of S-params to DC and to 20 GHz.
- Jitter
  - Jitter is Phase Modulation at 1.1 GHz
  - Amplitude 0.3 UIpp
- Tools
  - MathCAD
  - MATLAB
  - ADS

Results, Eye Diagrams

- Note: Most Eyes are Poor. Instead of Measuring Eye Opening (difficult) and Putting This Into A Spreadsheet, the Actual Eyes are Presented
- Format is always
  - Top = No equalization
  - Middle = Optimized for Duobinary
  - Bottom = Optimized for NRZ
- SDD21 Magnitude Plot Included

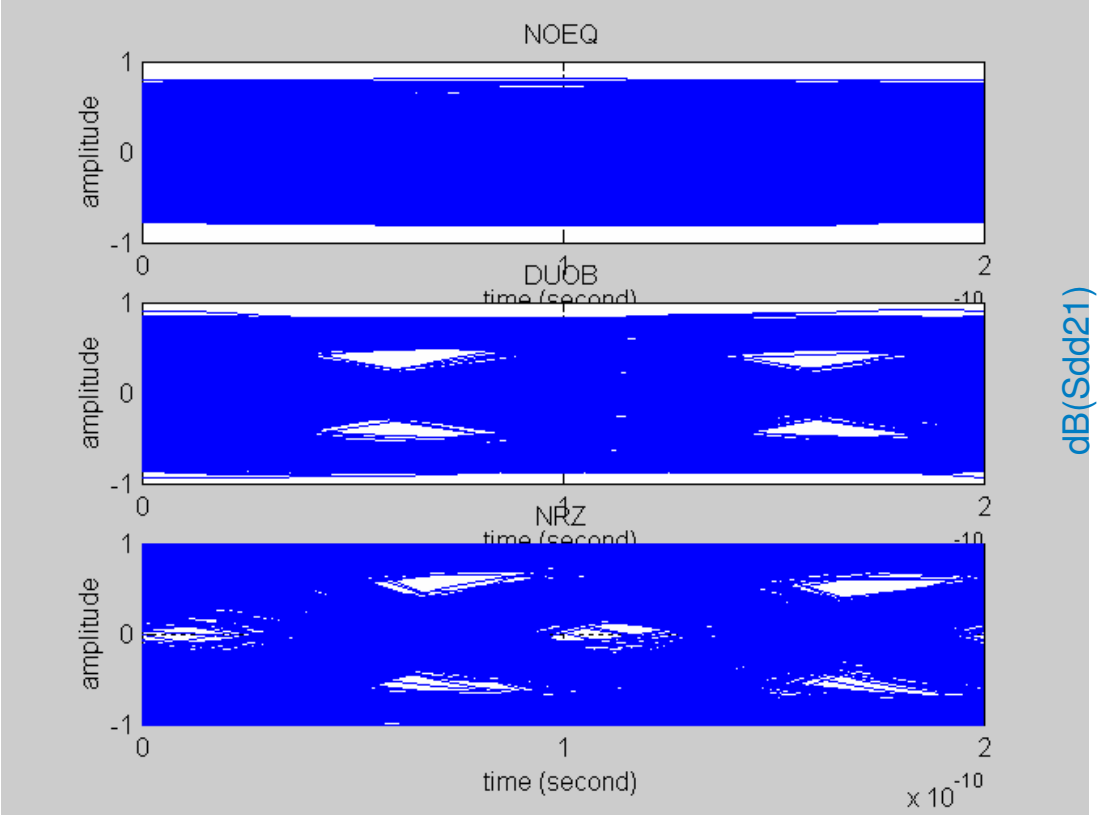
Tyco Case 1

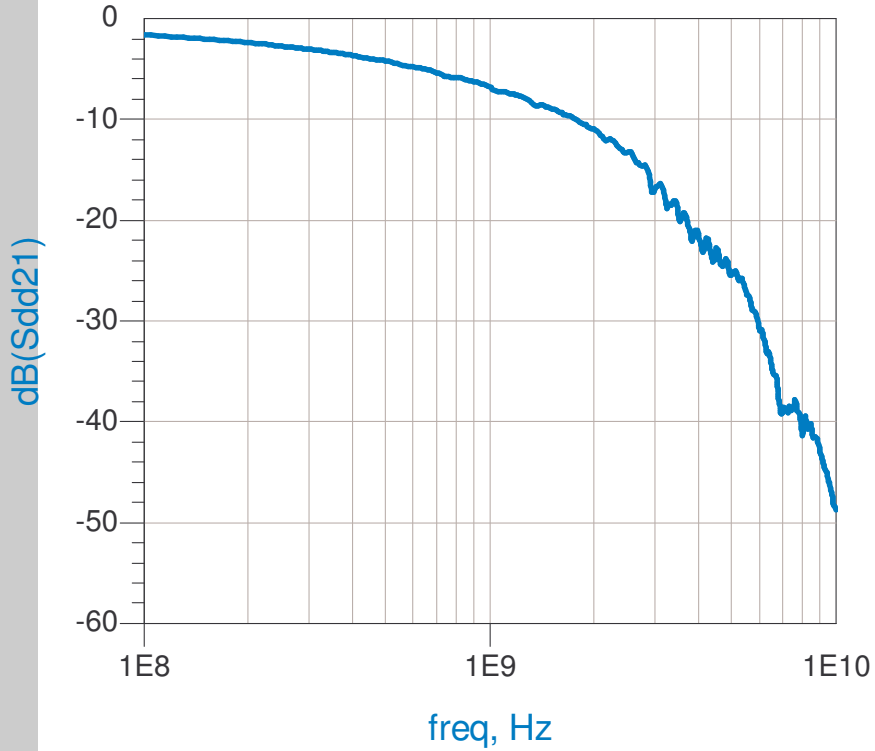




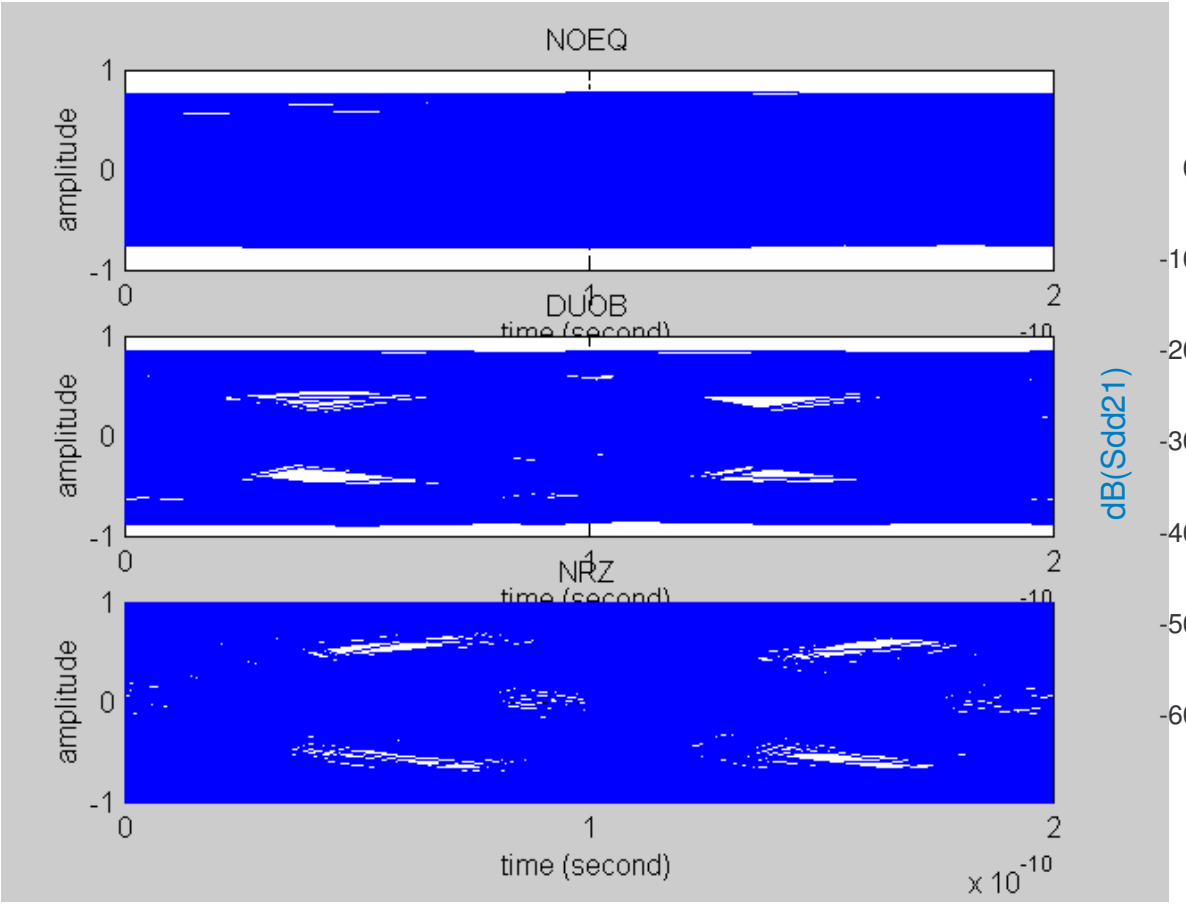
Top = No Equalization
Mid = Duobinary Equalization
Bottom = NRZ Equalization

Tyco Case 2


NOEQ
DUOB
NRZ
amplitude
time (second)
x 10^-10


dB(Sdd21)
0
-10
-20
-30
-40
-50
-60
1E8
1E9
1E10
freq, Hz

Tyco Case 3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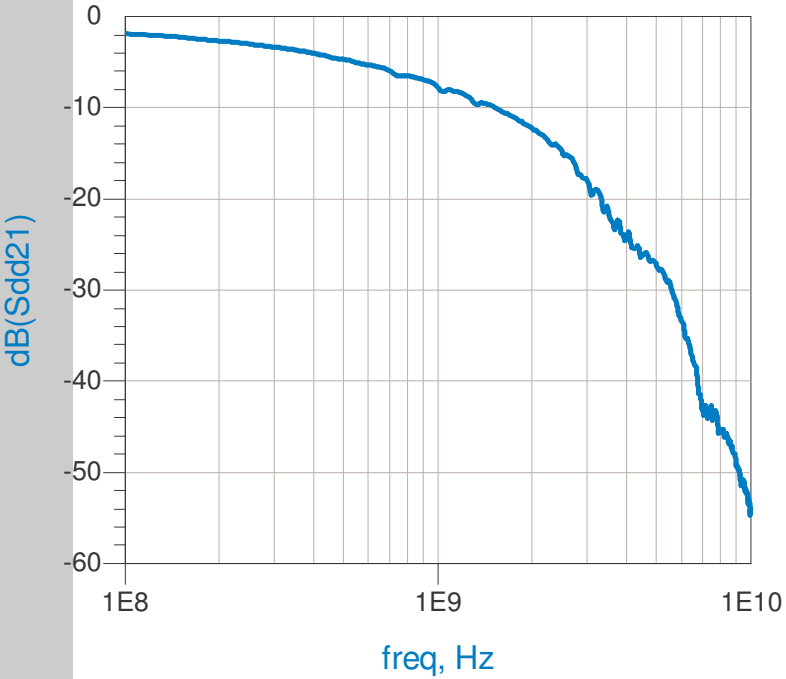
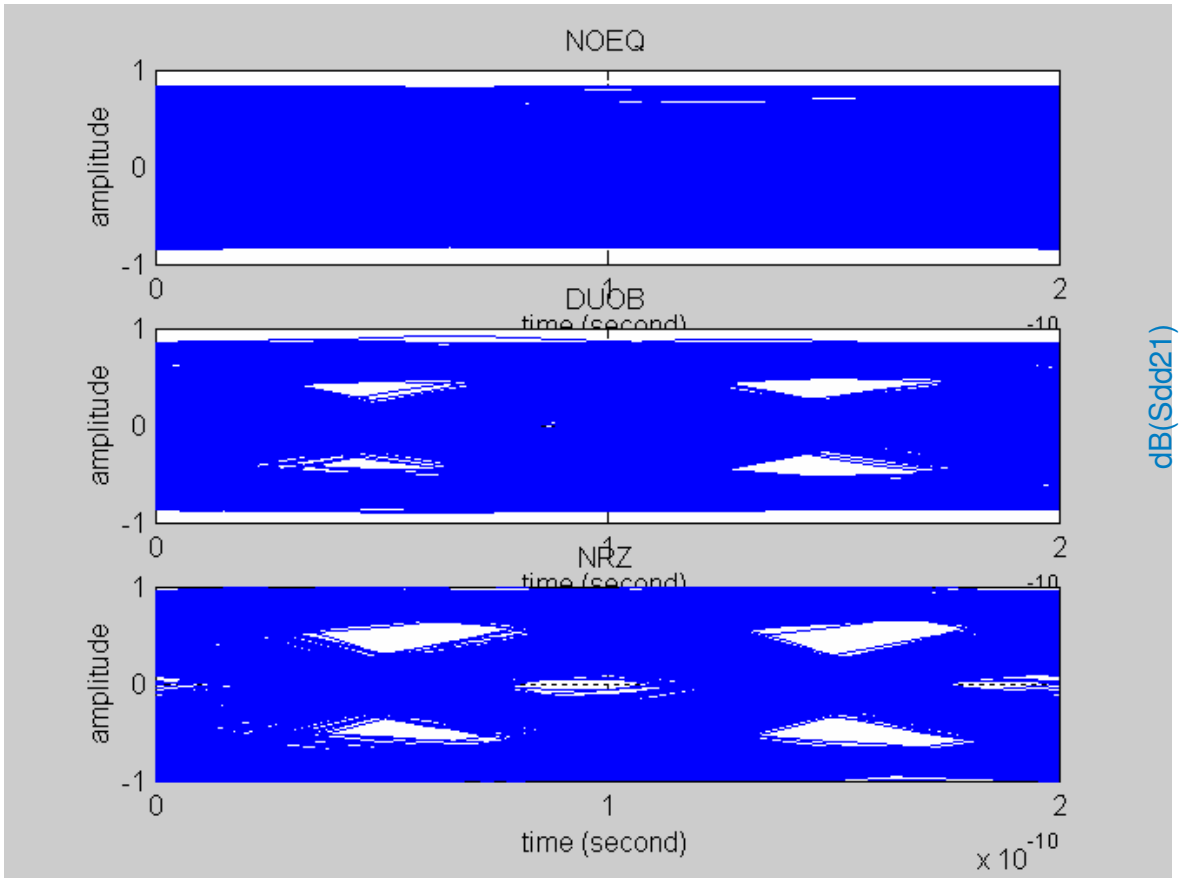
DUOB
NRZ
amplitude
time (second)
x 10^-10


dB(Sdd21)
freq, Hz
1E8
1E9
1E10

Tyco Case 4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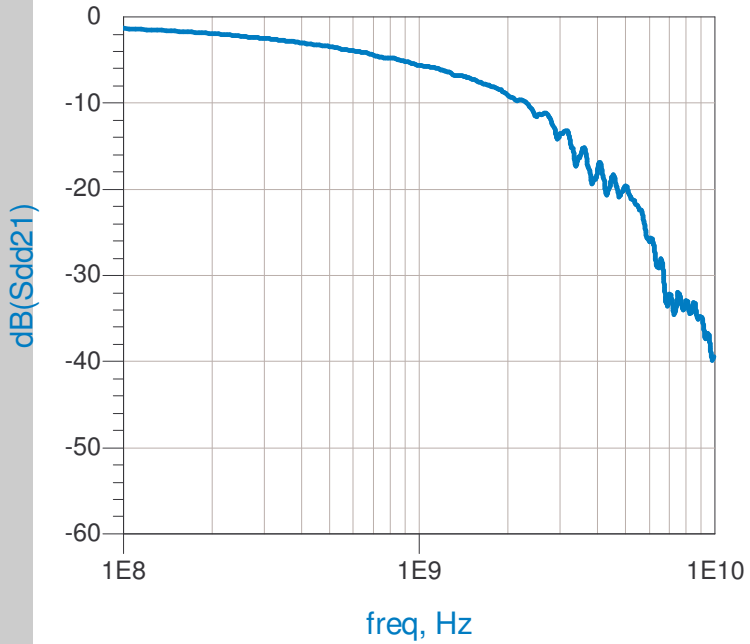
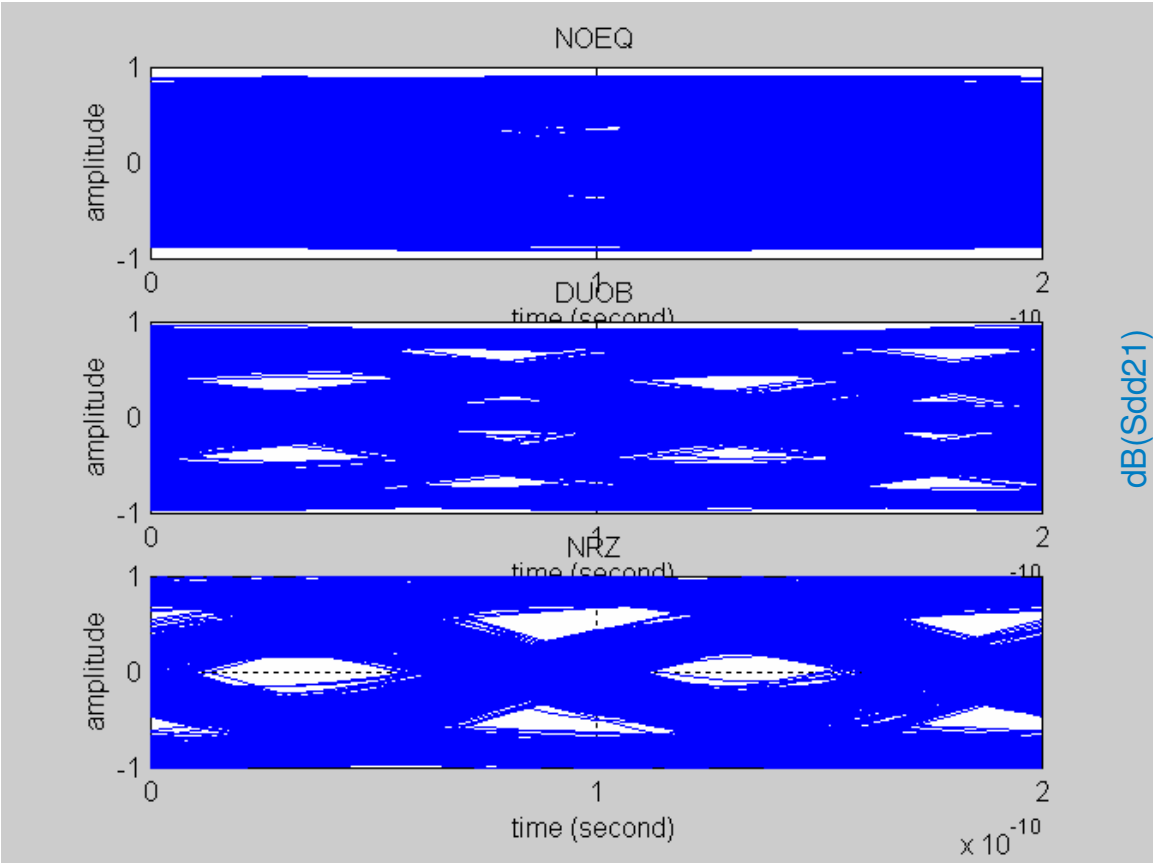
DUOB
NRZ
amplitude
time (second)
x 10^-10


dB(Sdd21)
freq, Hz
1E8
1E9
1E10

Tyco Case 5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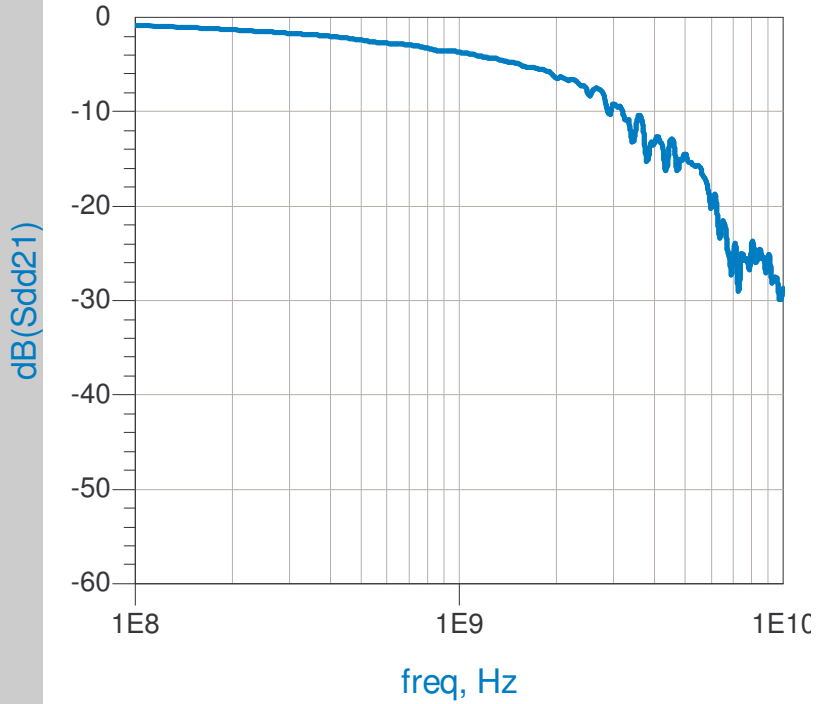
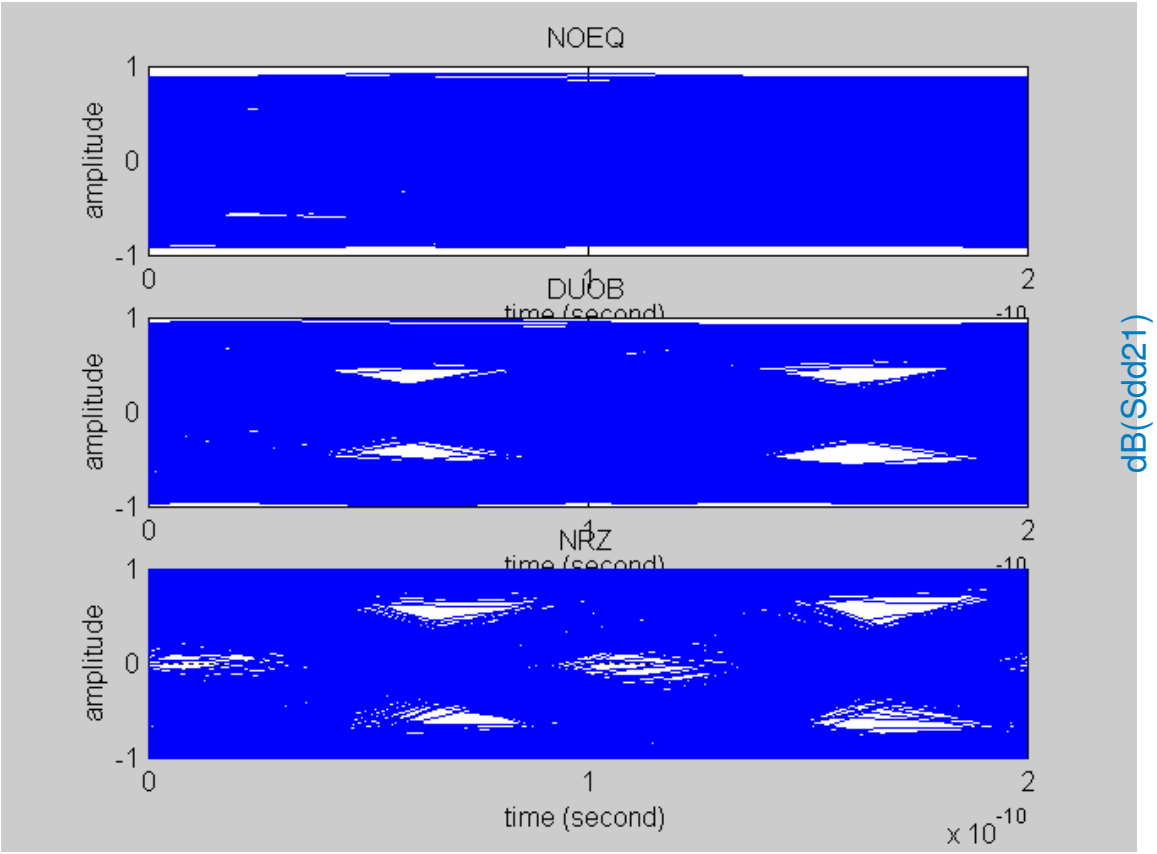
DUOB
NRZ
amplitude
time (second)
x 10^-10


dB(Sdd21)
freq, Hz
1E8
1E9
1E10

Tyco Case 6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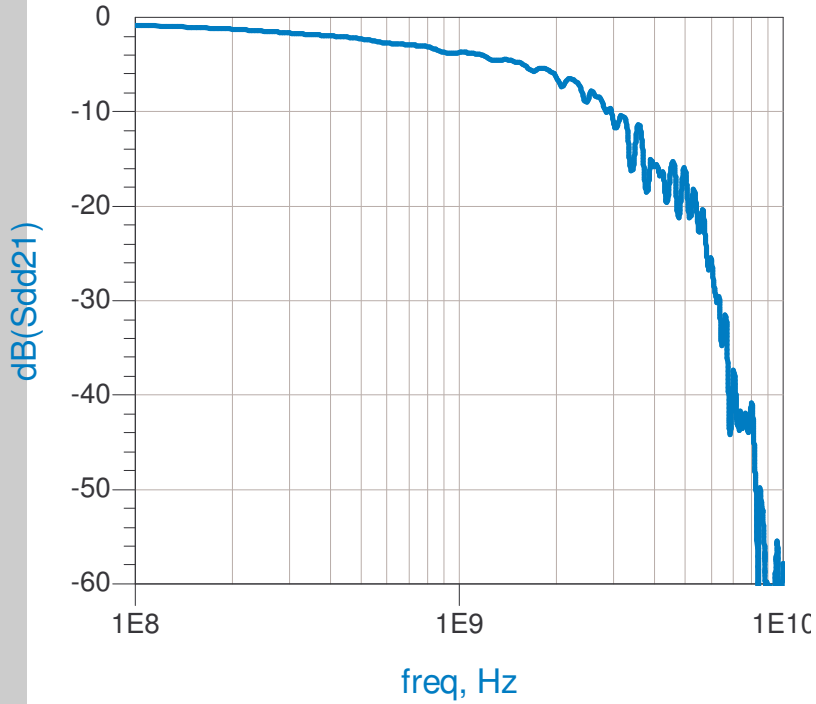
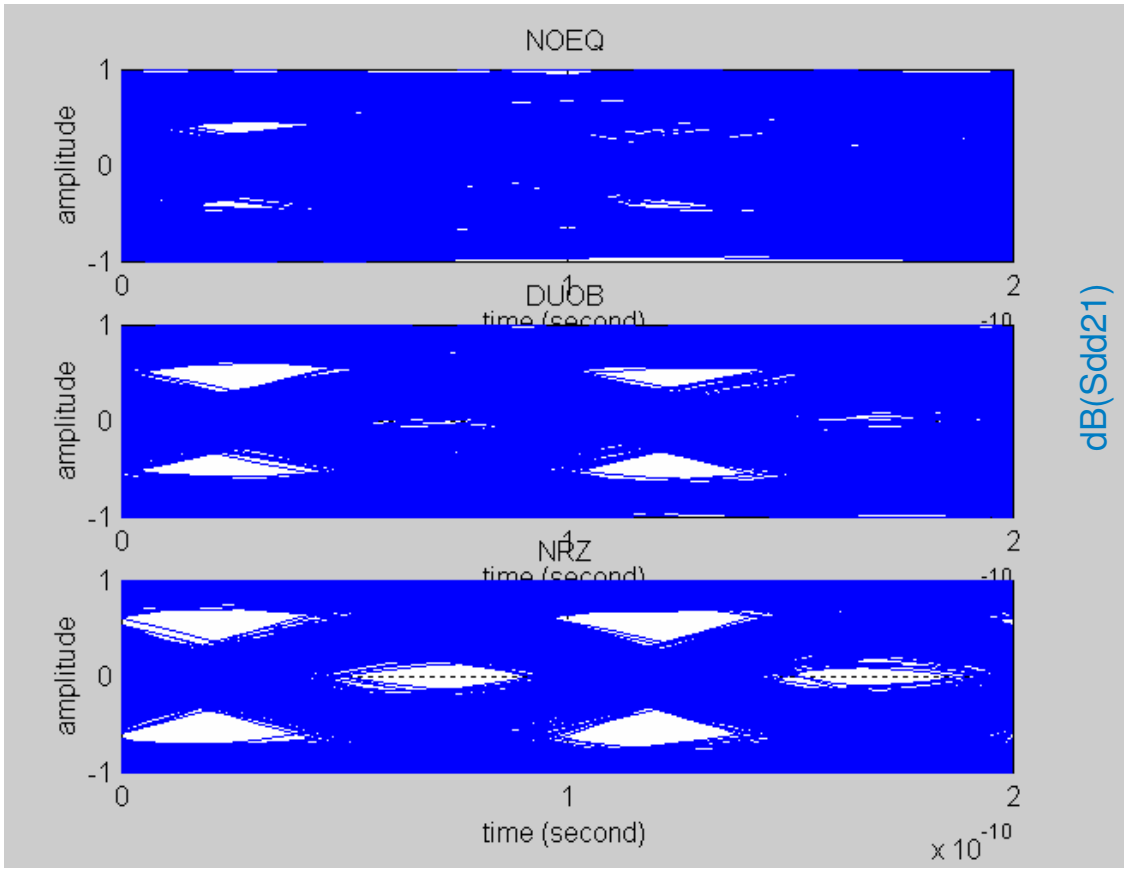
DUOB
NRZ
amplitude
time (second)
x 10^-10


dB(Sdd21)
freq, Hz
1E8
1E9

Tyco Case 7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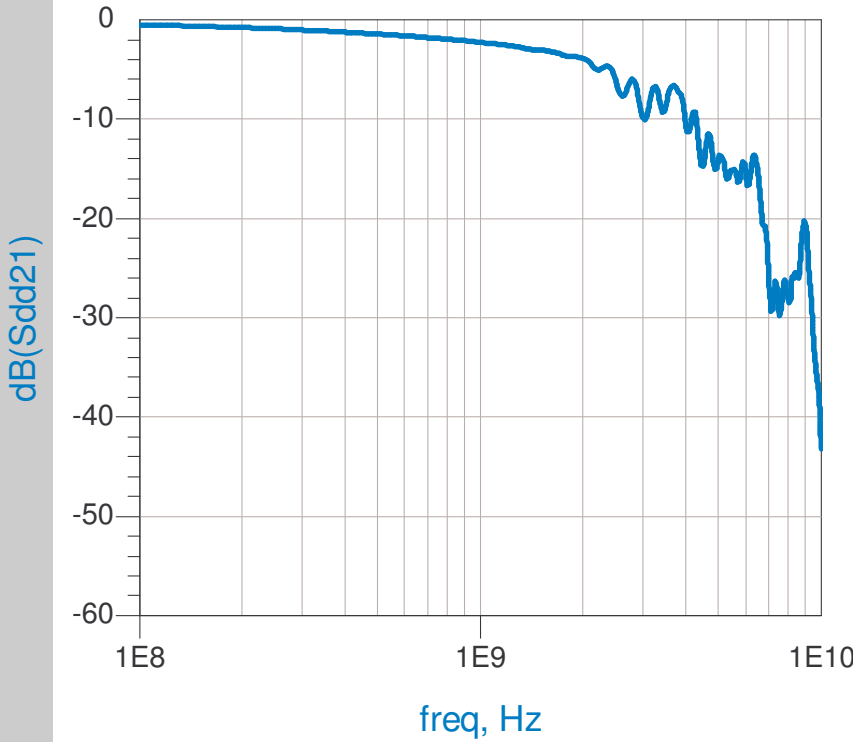
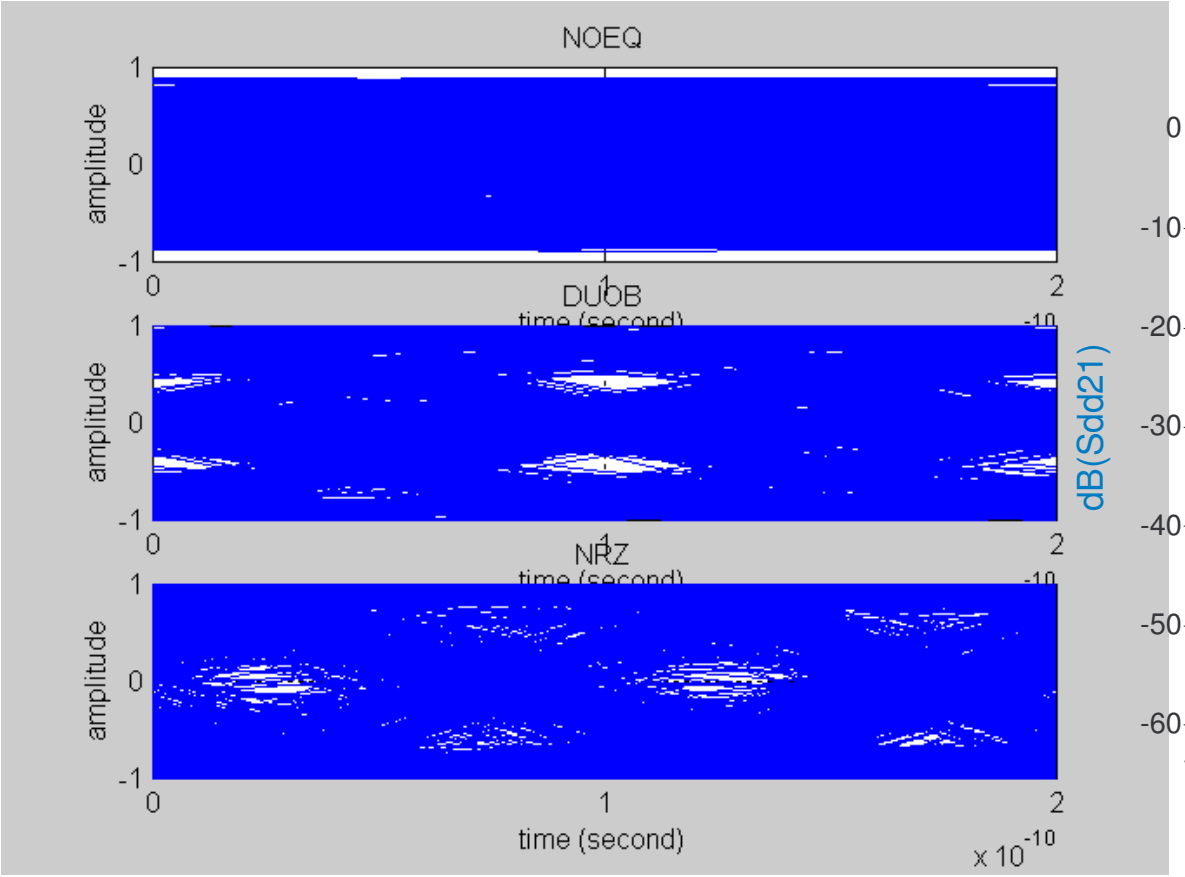
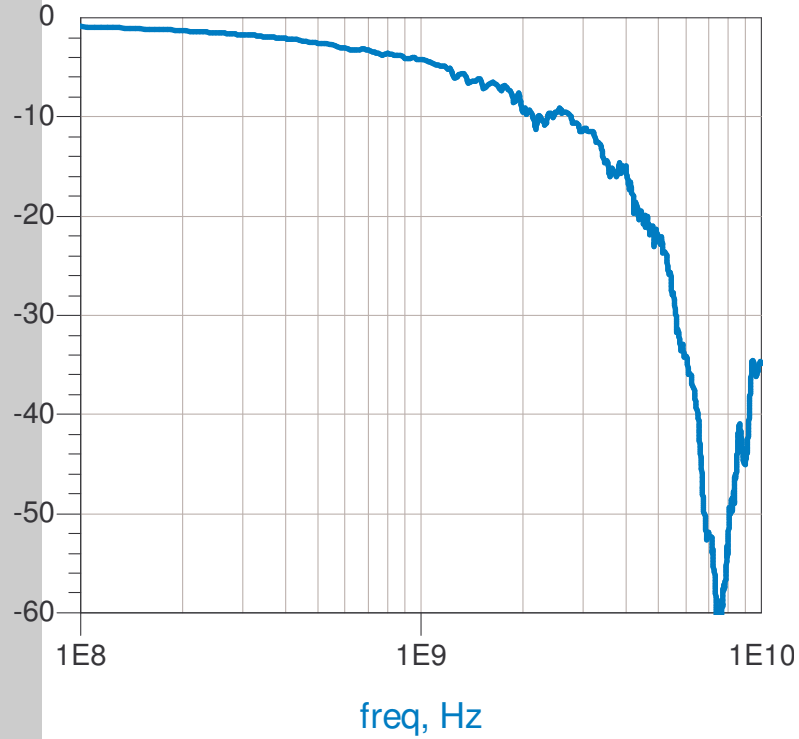
DUOB
NRZ
amplitude
time (second)
x 10^-10

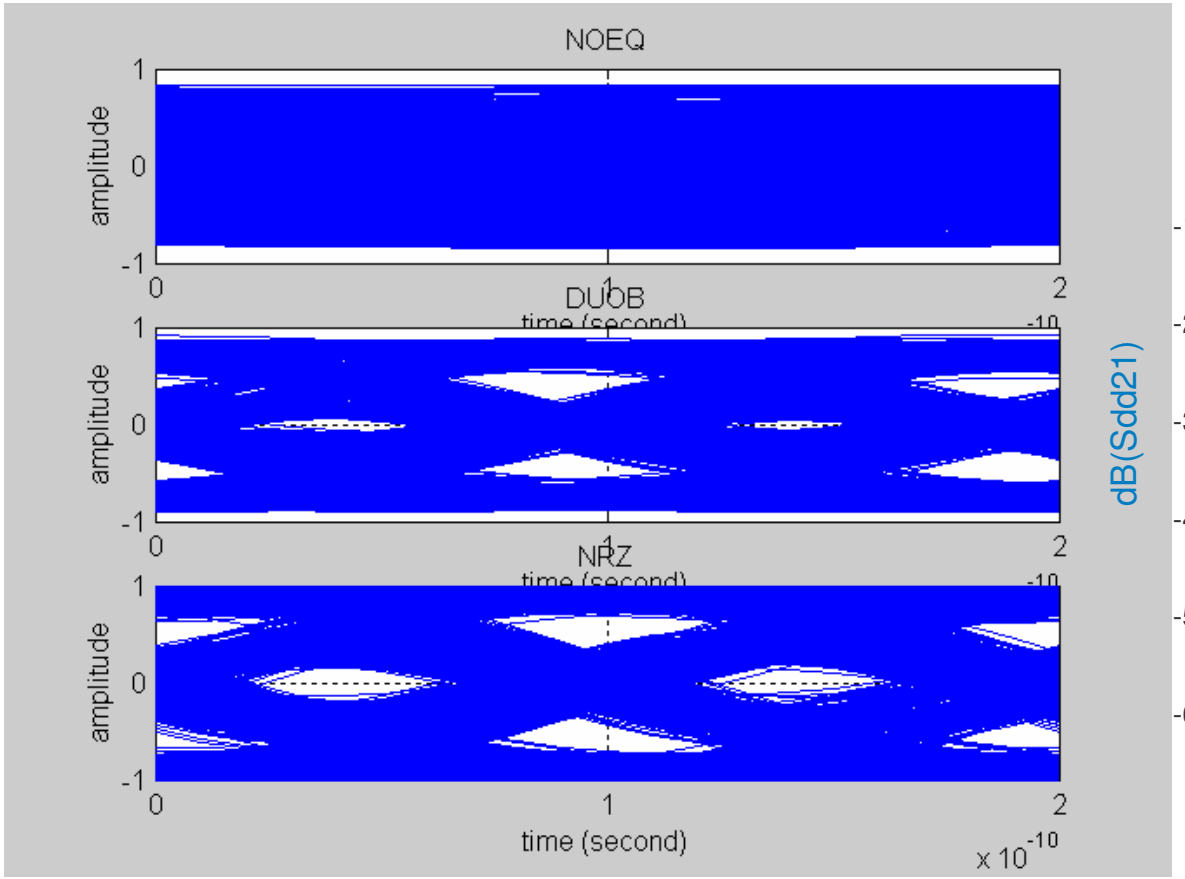

dB(Sdd21)
freq, Hz
0
-10
-20
-30
-40
-50
-60
1E8
1E9
1E10

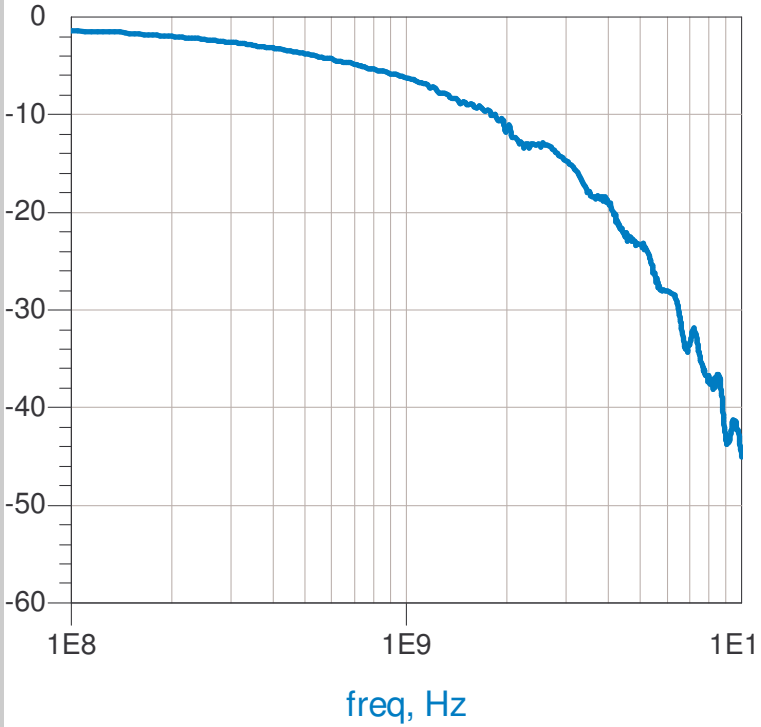
Molex 25 Inch, No Backdrill



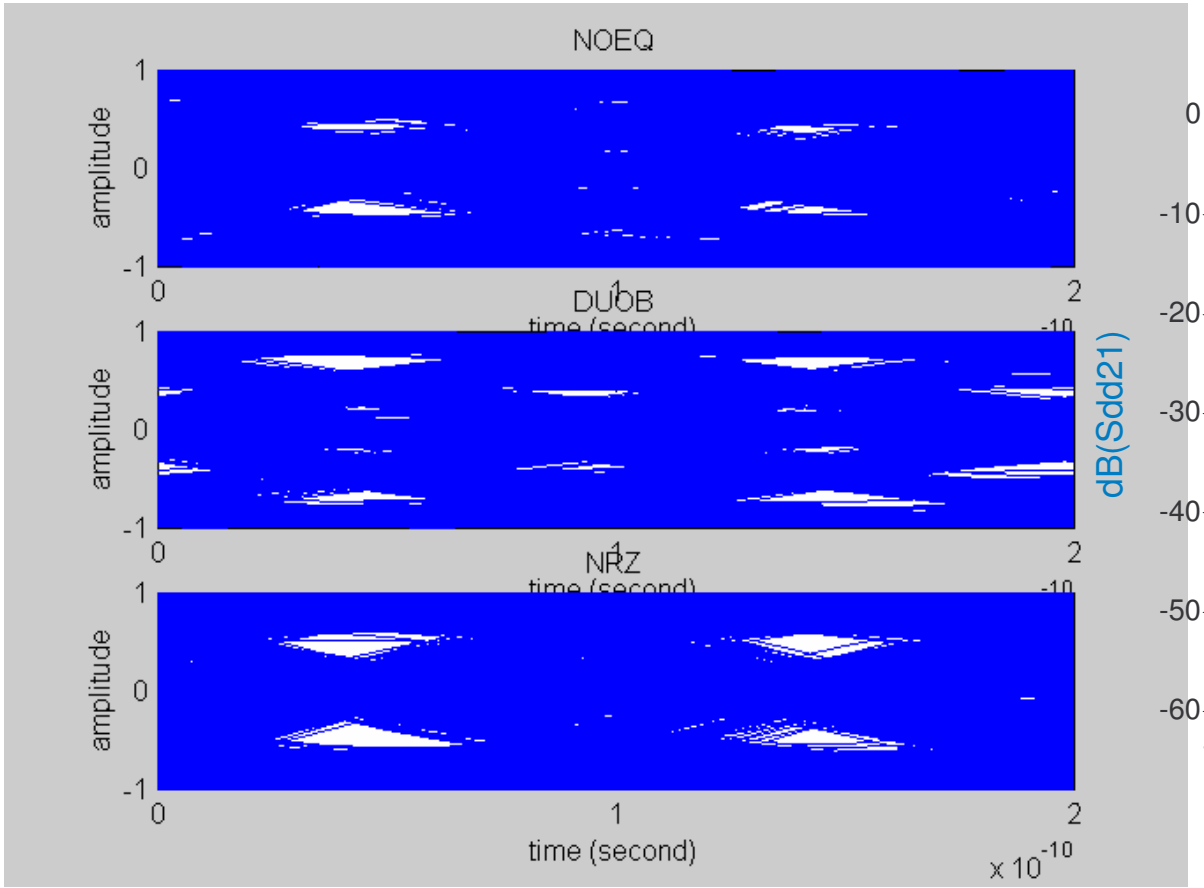


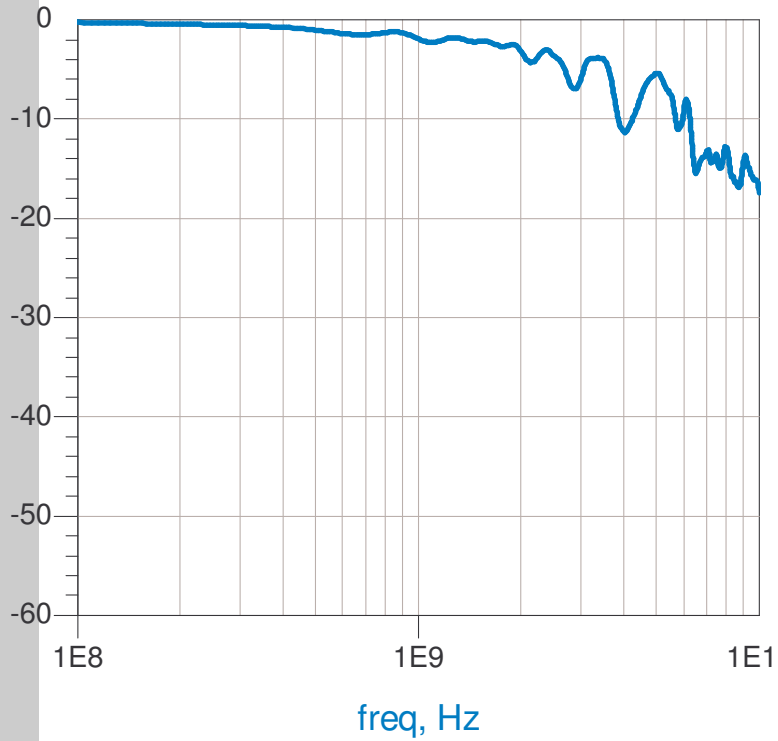
Molex 40 Inch, Backdrilled



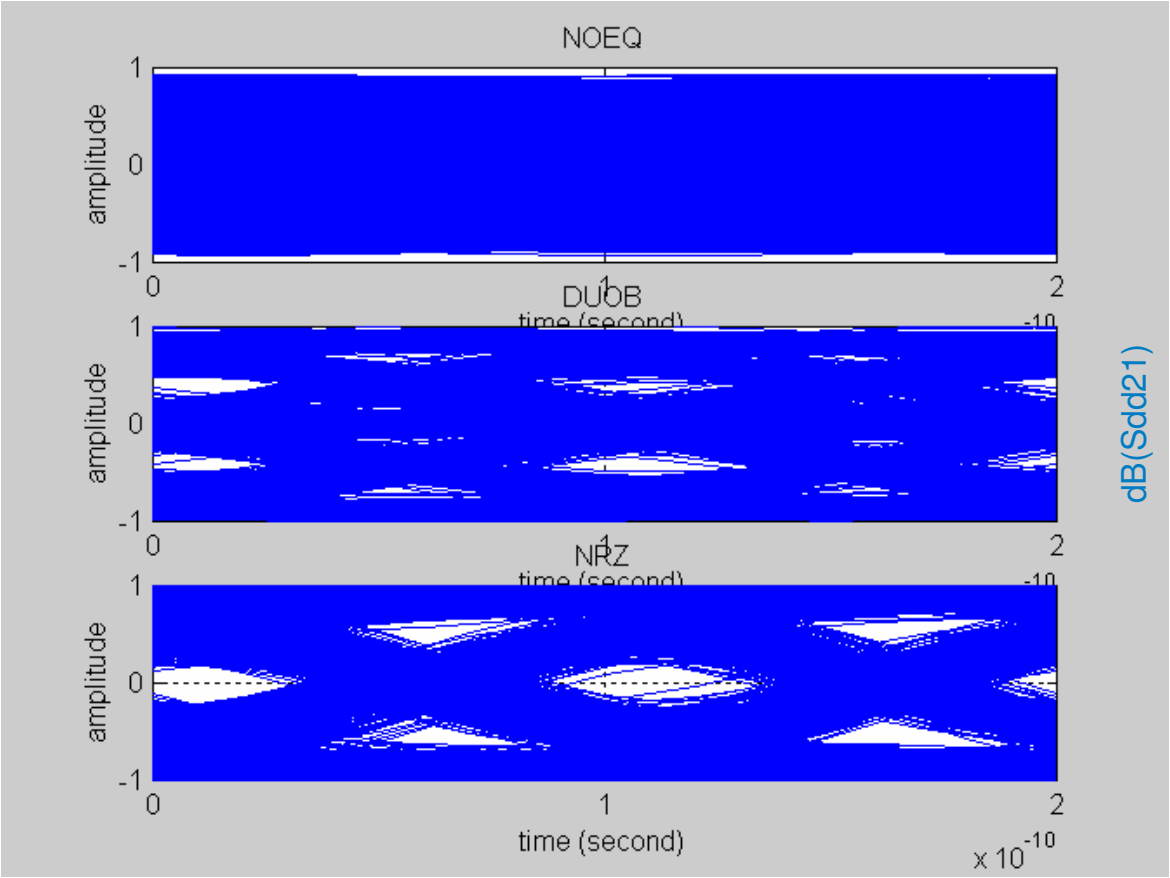


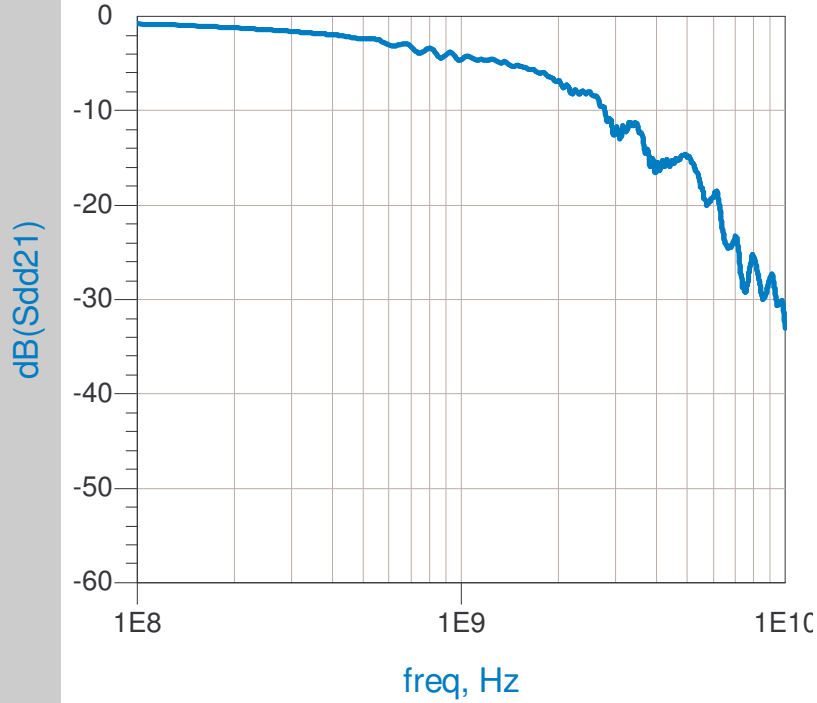
Intel B1


NOEQ
DUOB
NRZ
amplitude
time (second)
x 10^-10

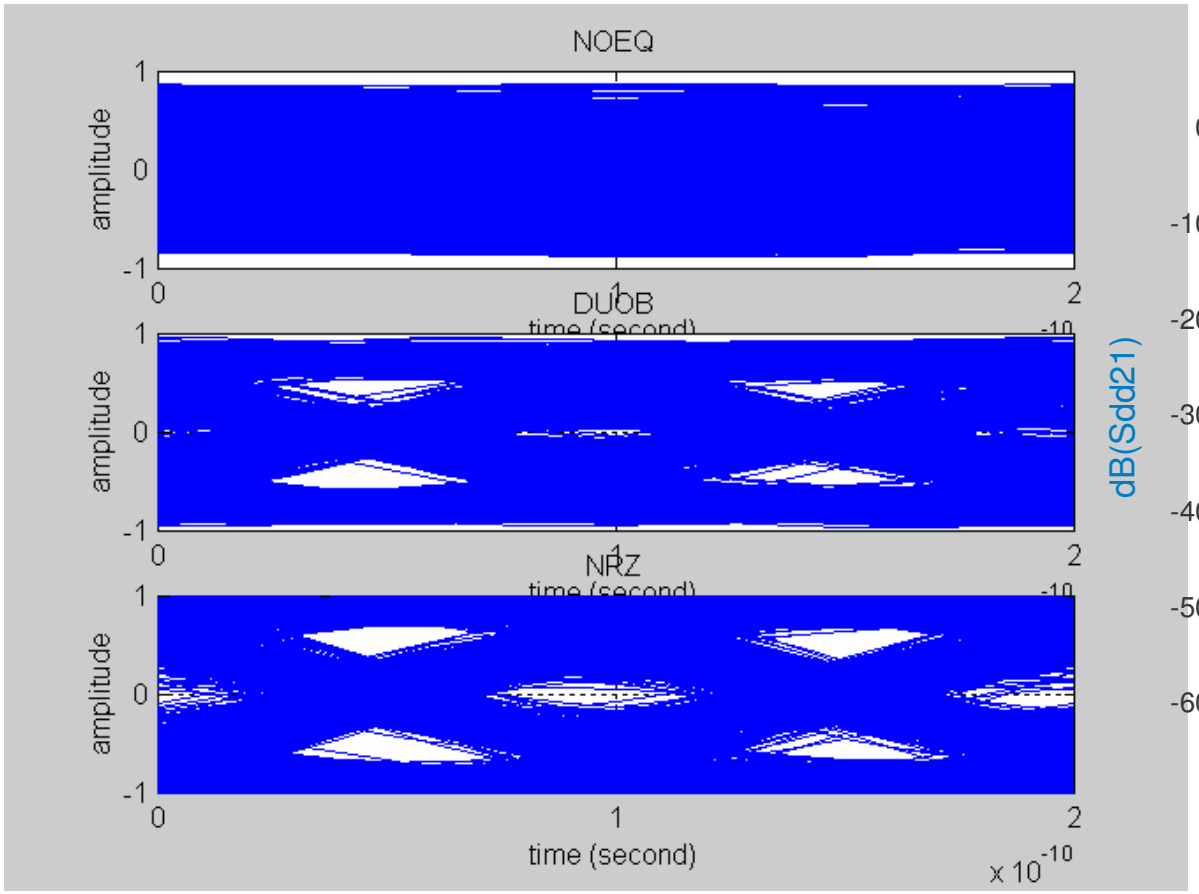

dB(Sdd21)
freq, Hz
1E8
1E9
1E1

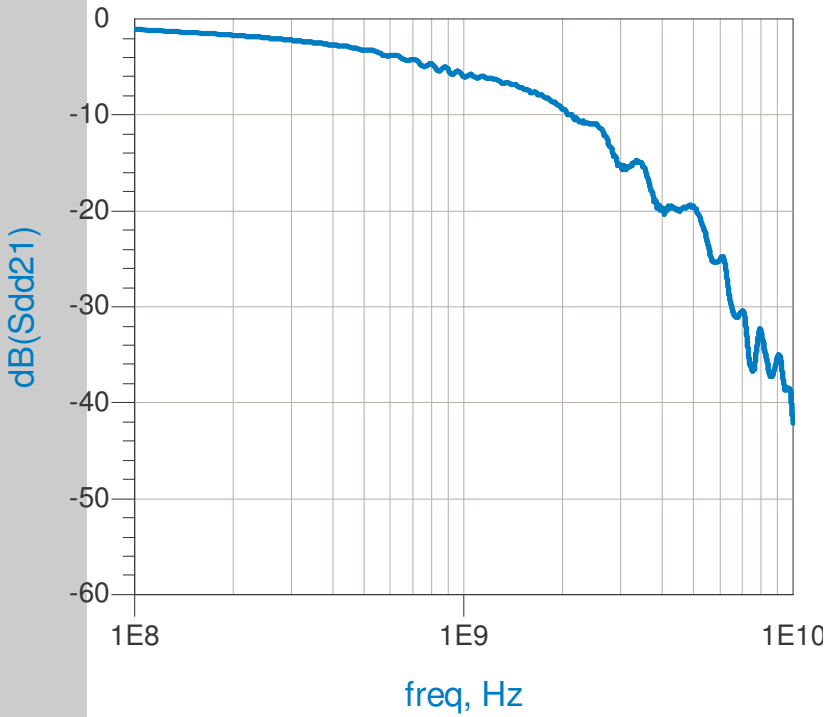
Intel B20


NOEQ
DUOB
NRZ
amplitude
1
0
-1
0
1
2
time (second)
x 10^-10

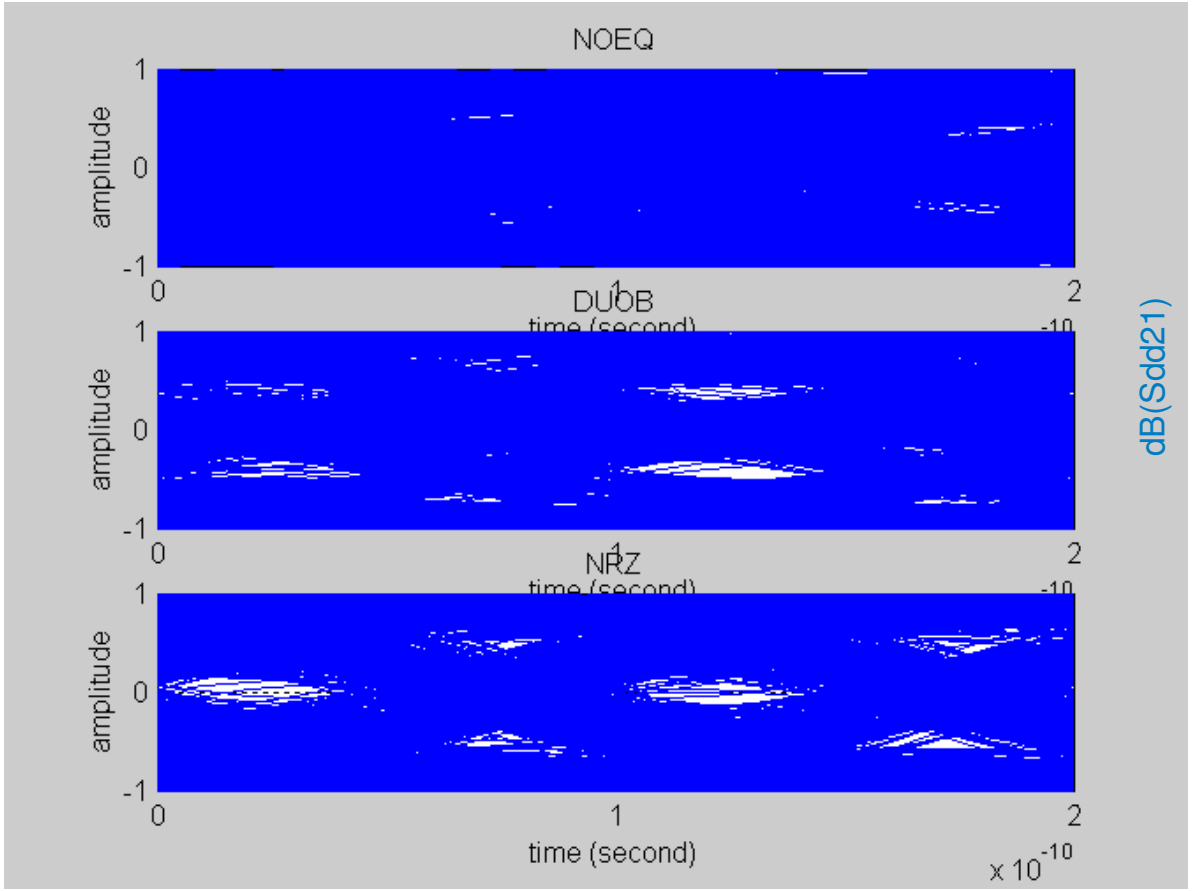

dB(Sdd21)
0
-10
-20
-30
-40
-50
-60
1E8
1E9
1E10
freq, Hz

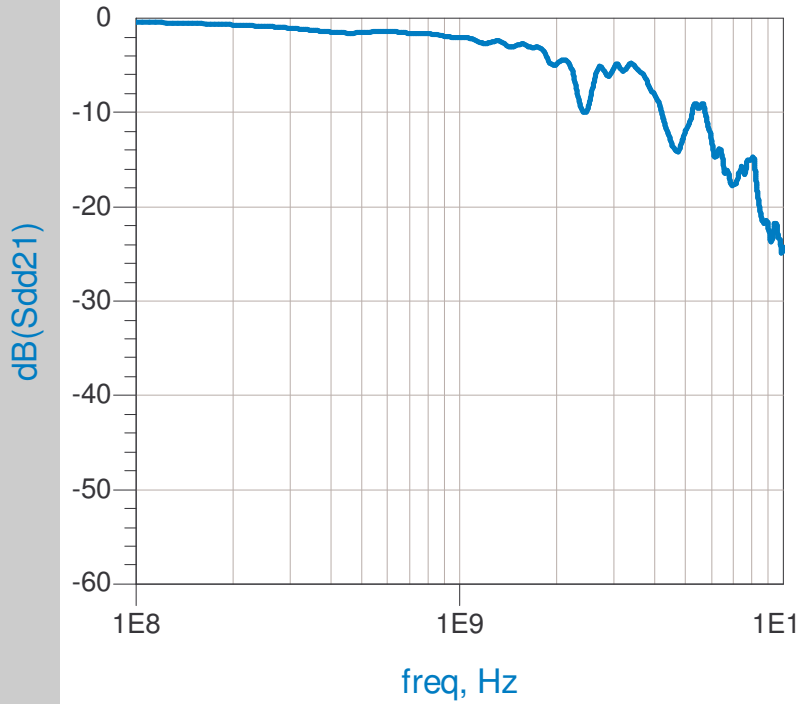
Intel B32


NOEQ
DUOB
NRZ
amplitude
time (second)
x 10^-10

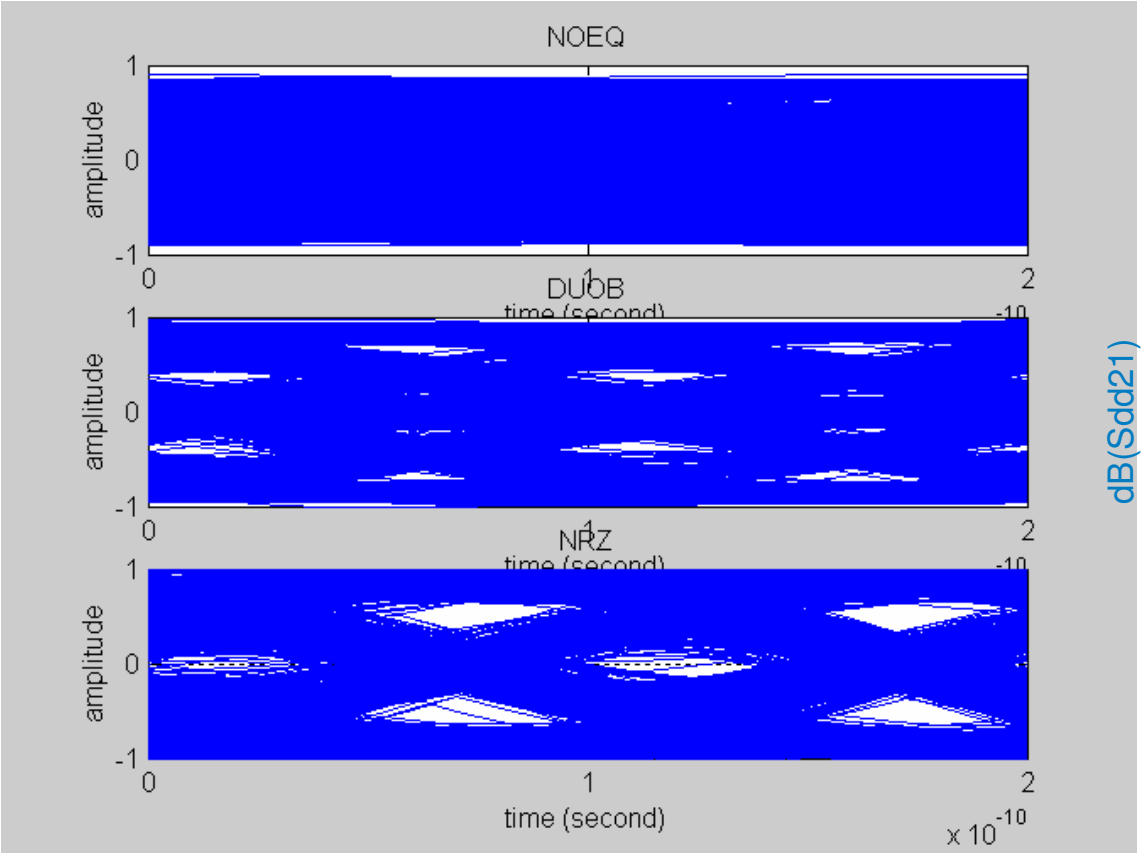

dB(Sdd21)
freq, Hz
1E8
1E9
1E10

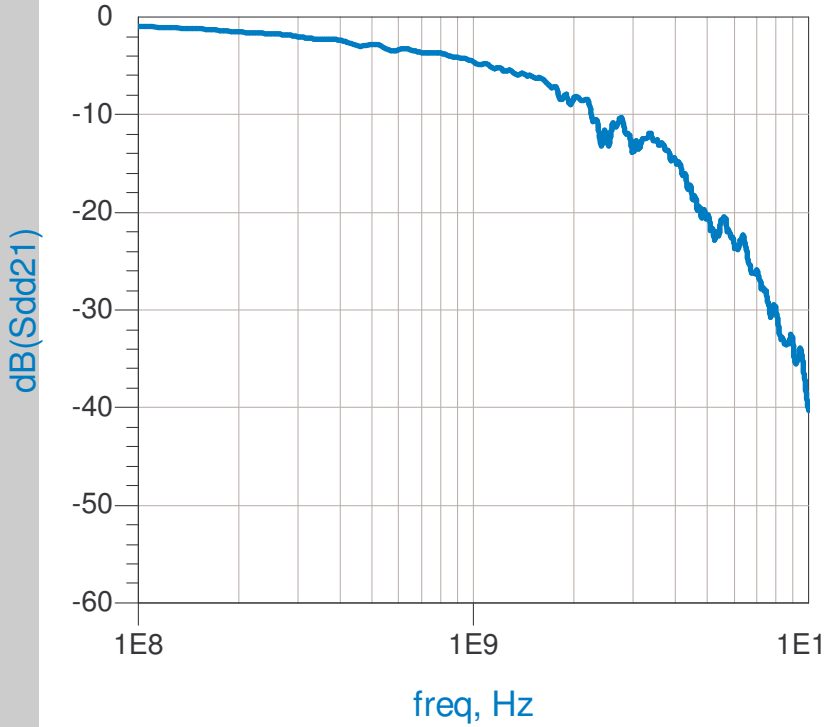
Intel M1


NOEQ
amplitude
1
0
-1
0
1
2
DUOB
amplitude
NRZ
amplitude
time (second)
x 10^-10

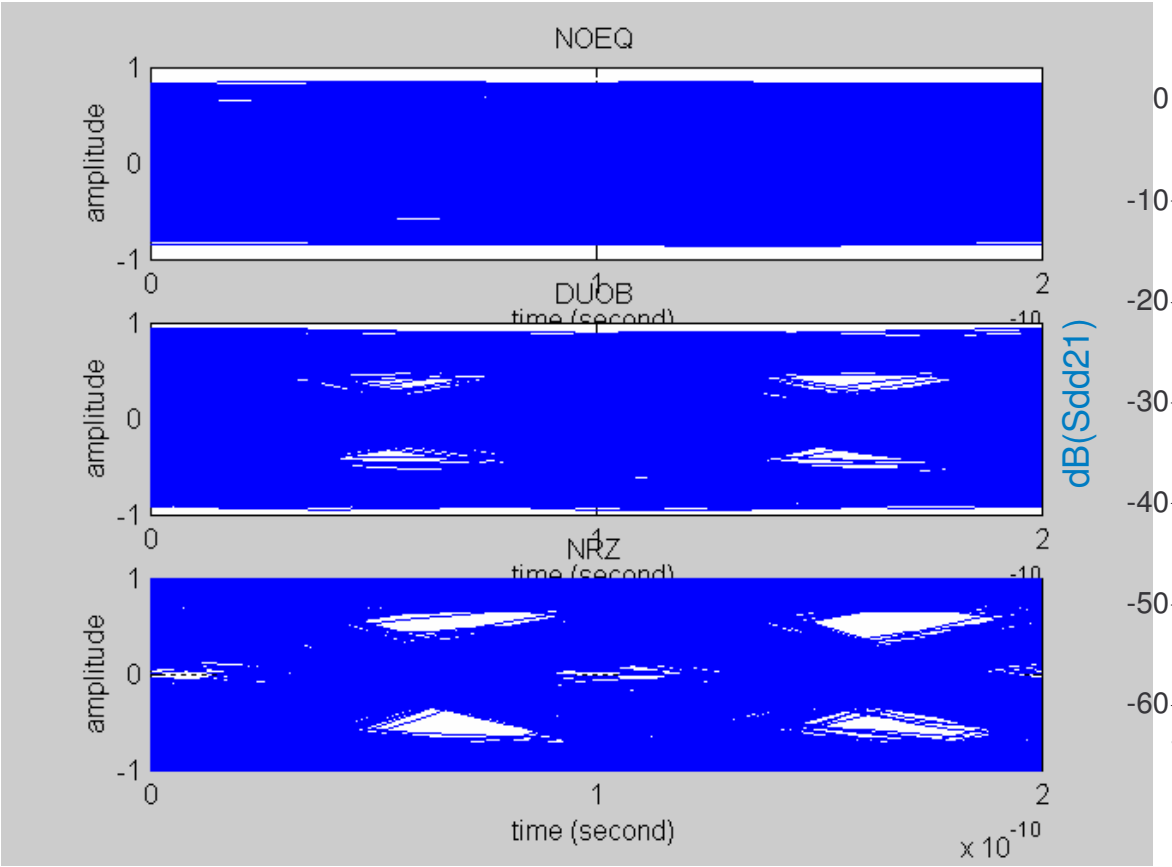

dB(Sdd21)
0
-10
-20
-30
-40
-50
-60
1E8
1E9
1E1
freq, Hz

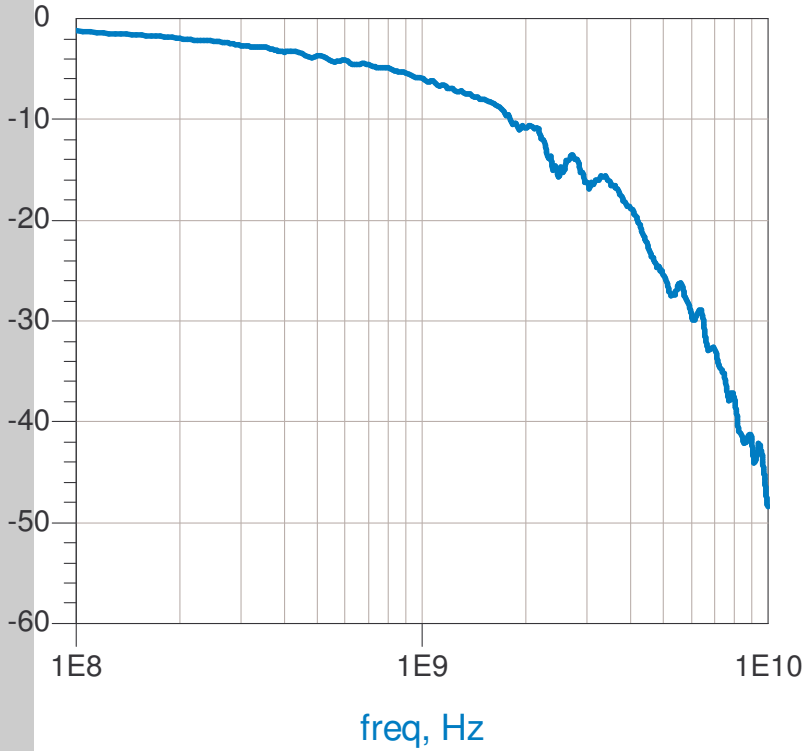
Intel M20


NOEQ
DUOB
NRZ
amplitude
1
0
-1
0
1
2
time (second)
x 10^-10

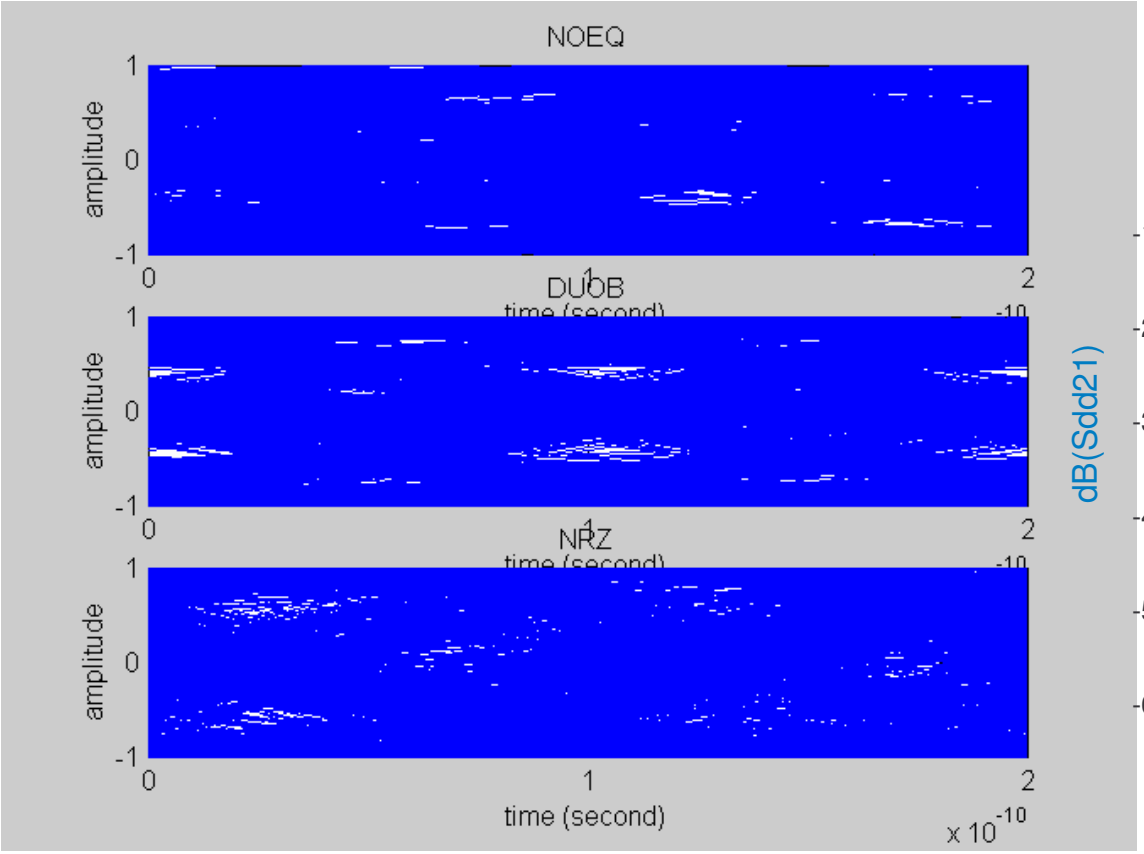

dB(Sdd21)
0
-10
-20
-30
-40
-50
-60
1E8
1E9
1E1
freq, Hz

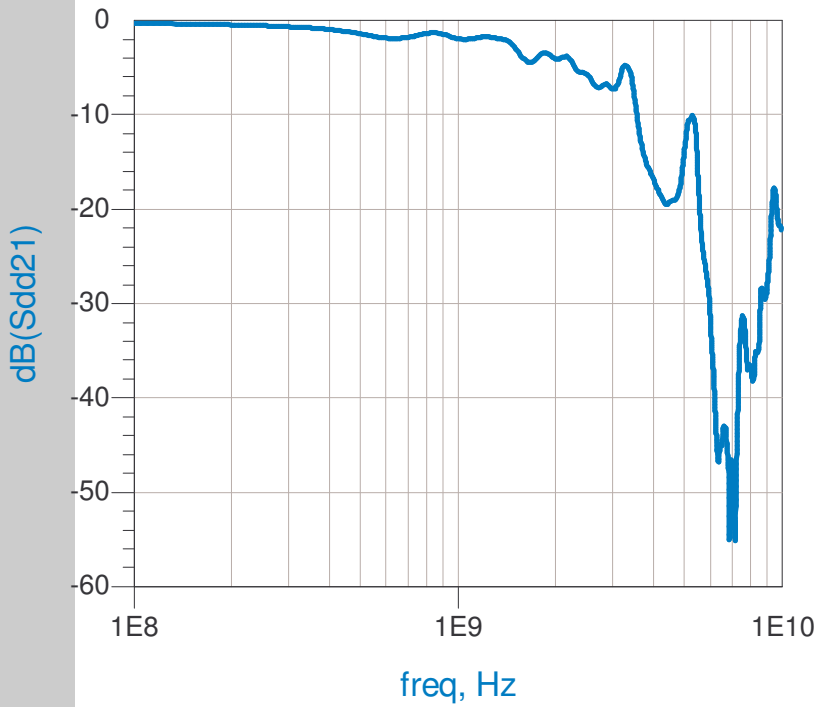
Intel M32


NOEQ
DUOB
NRZ
amplitude
time (second)
x 10^-10

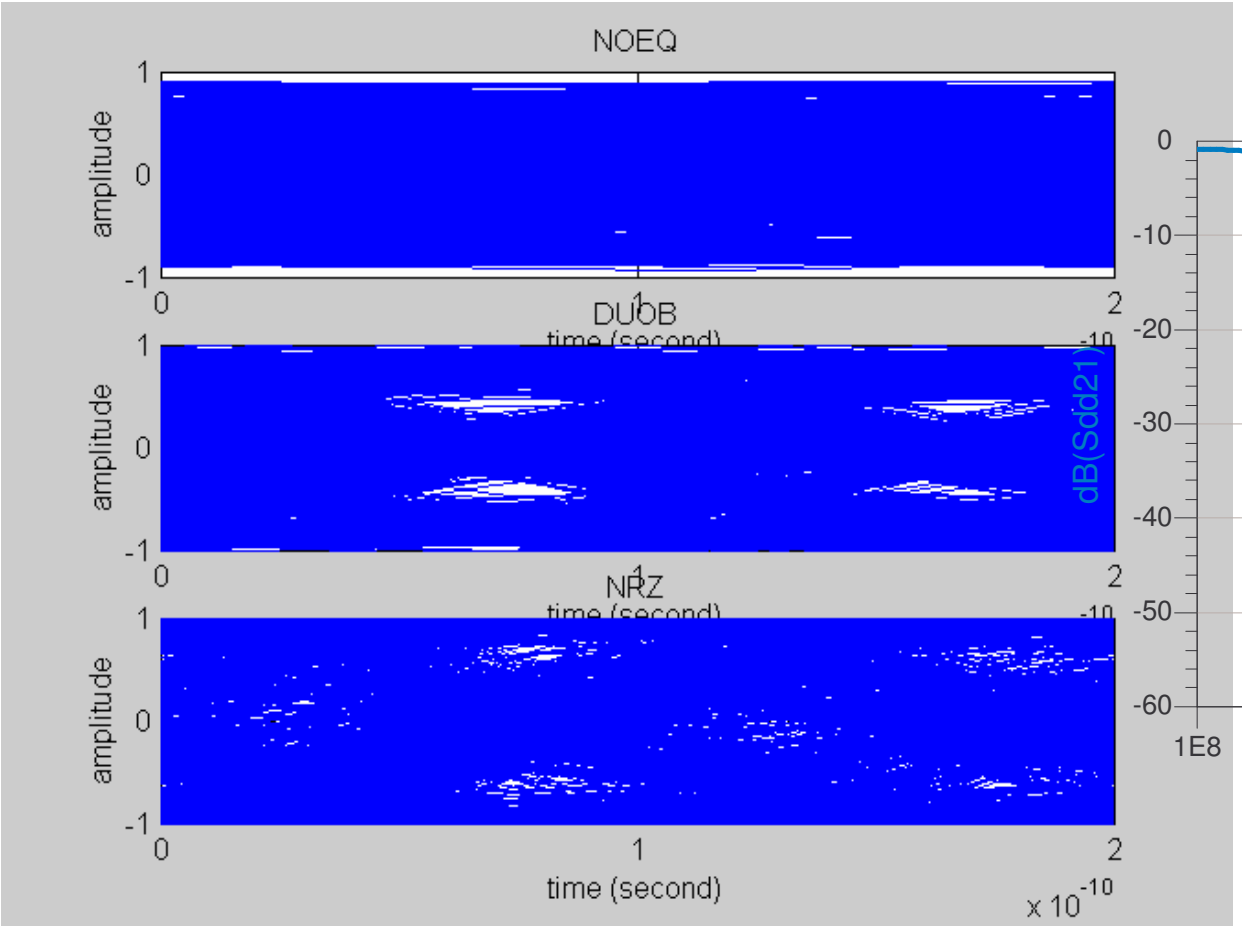

dB(Sdd21)
freq, Hz
1E8
1E9
1E10

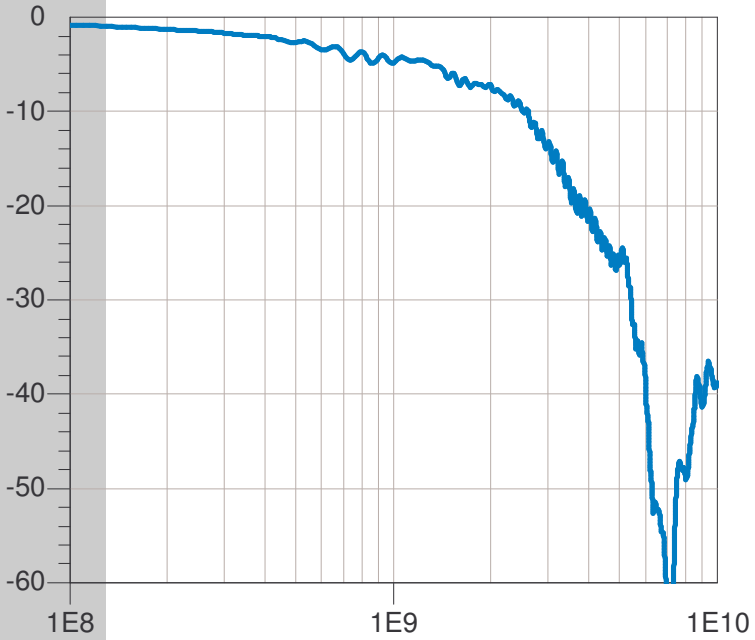
Intel T1


NOEQ
DUOB
NRZ
amplitude
1
0
-1
0
1
2
time (second)
x 10^-10

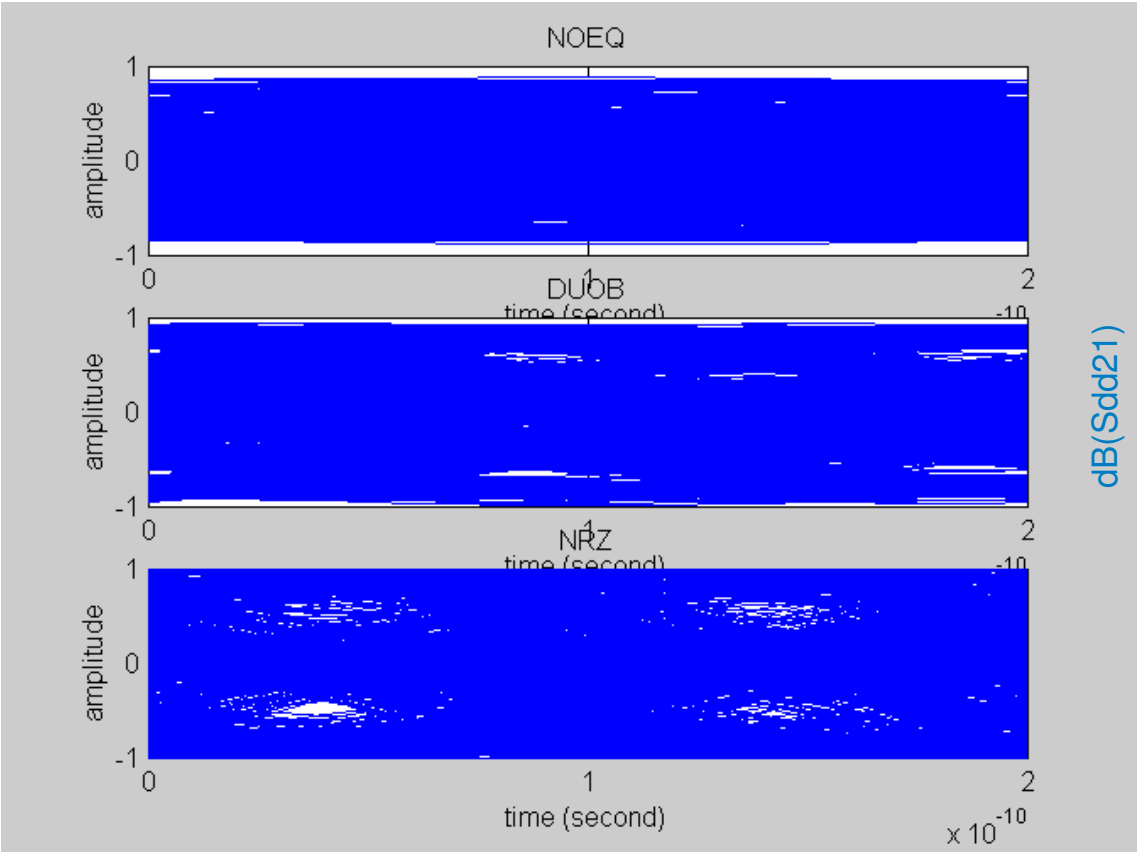

dB(Sdd21)
0
-10
-20
-30
-40
-50
-60
1E8
1E9
1E10
freq, Hz

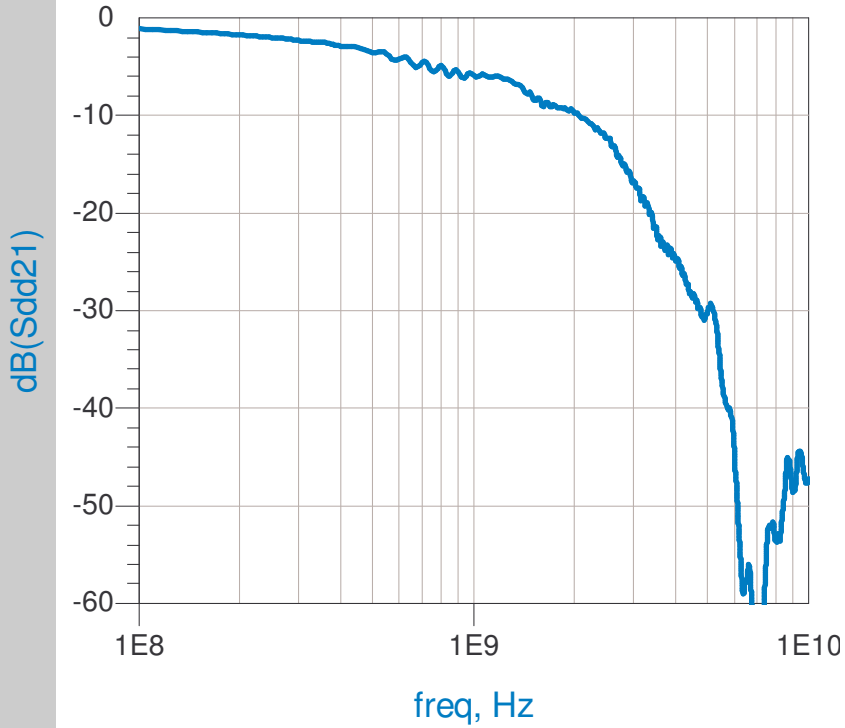
Intel T20


NOEQ
DUOB
NRZ
amplitude
1
0
-1
0
1
2
time (second)
x 10^-10


dB(Sdd21)
0
-10
-20
-30
-40
-50
-60
1E8
1E9
1E10
freq, Hz

Intel T32


NOEQ
DUOB
NRZ
amplitude
1
0
-1
0
1
2
time (second)
x 10^-10


dB(Sdd21)
0
-10
-20
-30
-40
-50
-60
1E8
1E9
1E10
freq, Hz

Conclusions from Duobinary and NRZ Comparative Simulations

- Duobinary is not immune to crosstalk and jitter effects
- Rx (DFE) equalization needed for both Duobinary and NRZ
- Curious Phenomenon:
  - NRZ Optimization frequently results in better DB eye than pure DB optimization
    - Correlates with lab waveforms
- Difference between Duobinary- and NRZ-optimized waveforms is incremental, not order of magnitude
- Beliefs:
  - For same BER…implementation complexity will be similar between DB and NRZ
  - Channels will drive implementation complexity, more than signaling does

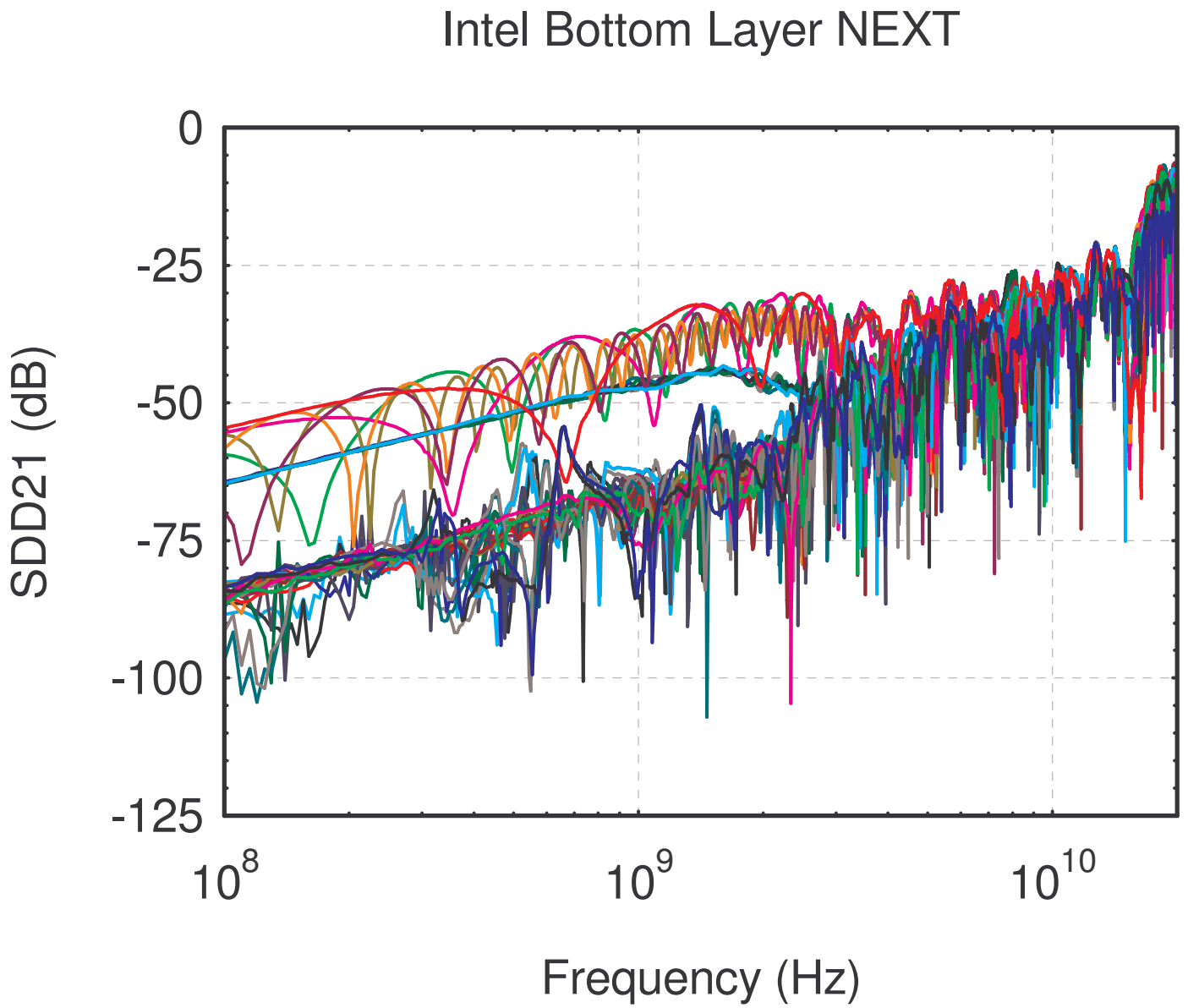
Acknowledgement

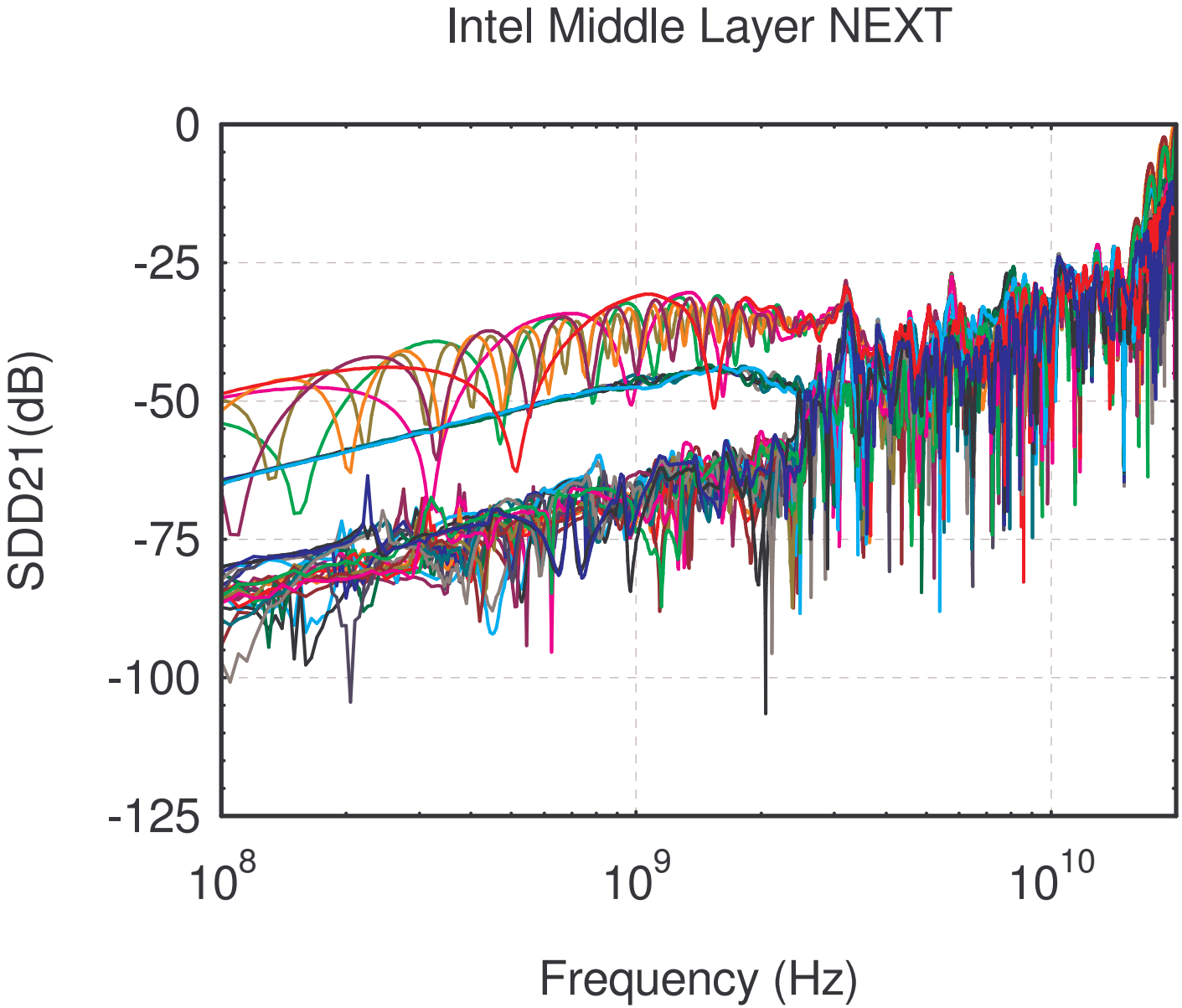
- Backplanes / Measurements
  - Tyco
  - Molex
  - Intel
- Assistance
  - Gourgen Onnasayan, Molex
  - Brian Seemann, Xilinx
  - Dan Hulse, Xilinx

Supporting Slides …

Worst Case Xtalk Channels

- Intel is B3 NEXT2
- Molex is INBOUND/sj3k3g3h3_SPARS.s4p
- Tyco is Case 7 N1


Intel Bottom Layer NEXT
0
-25
-50
-75
-100
-125
SDD21 (dB)
10^8
10^9
10^10
Frequency (Hz)


Intel Middle Layer NEXT
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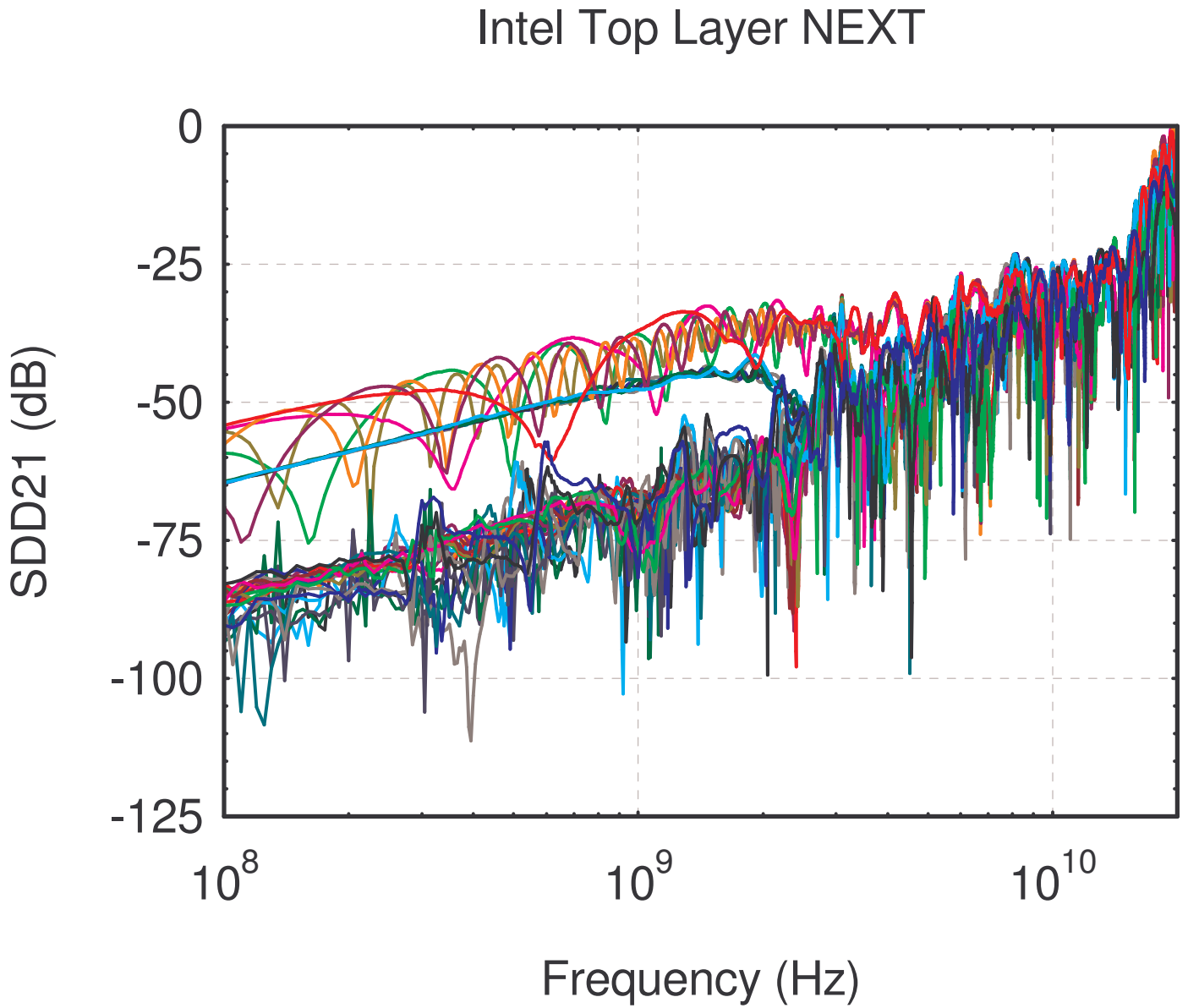
-25
-50
-75
-100
-125
SDD21(dB)
10^8
10^9
10^10
Frequency (Hz)


Intel Top Layer NEXT
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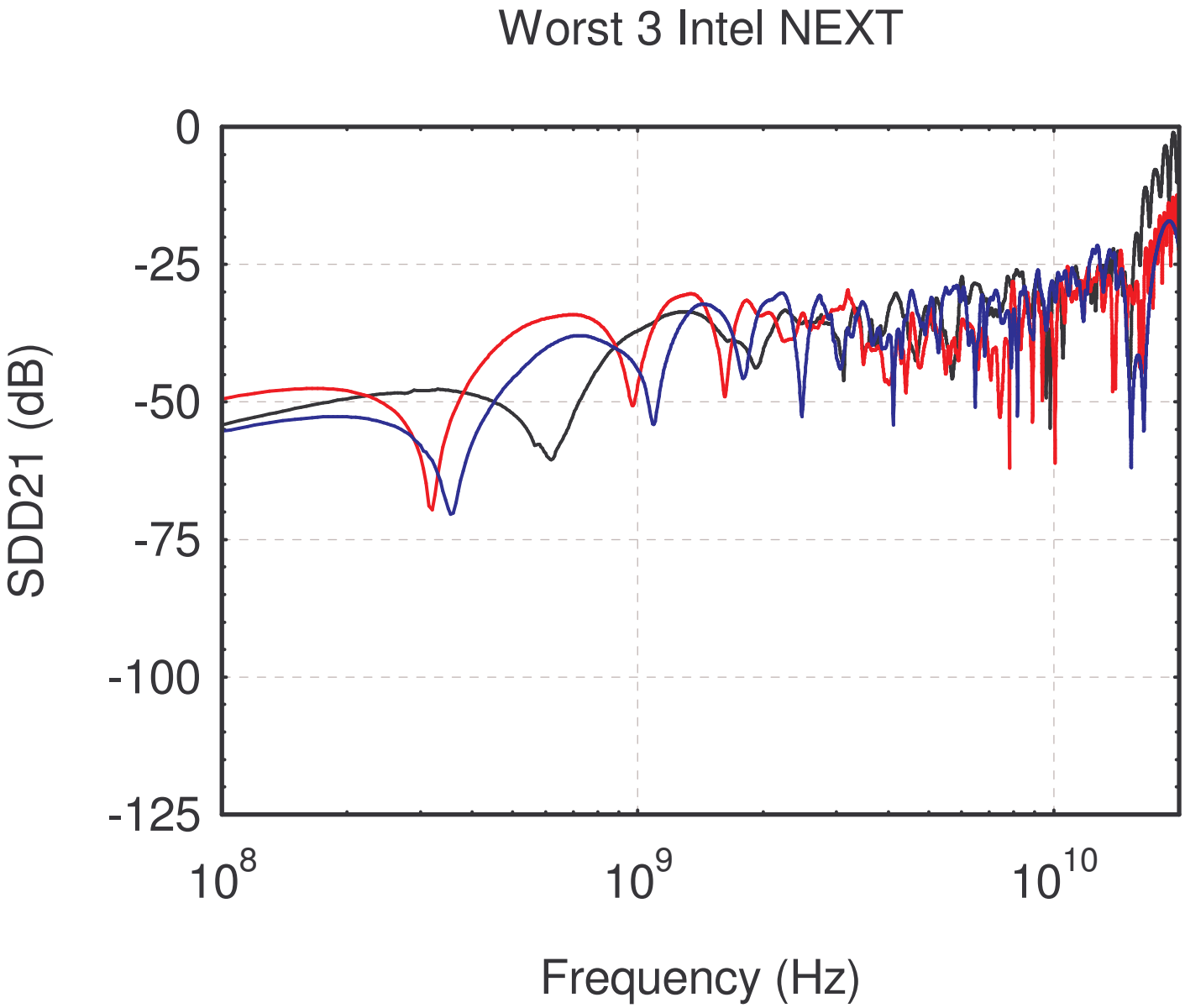
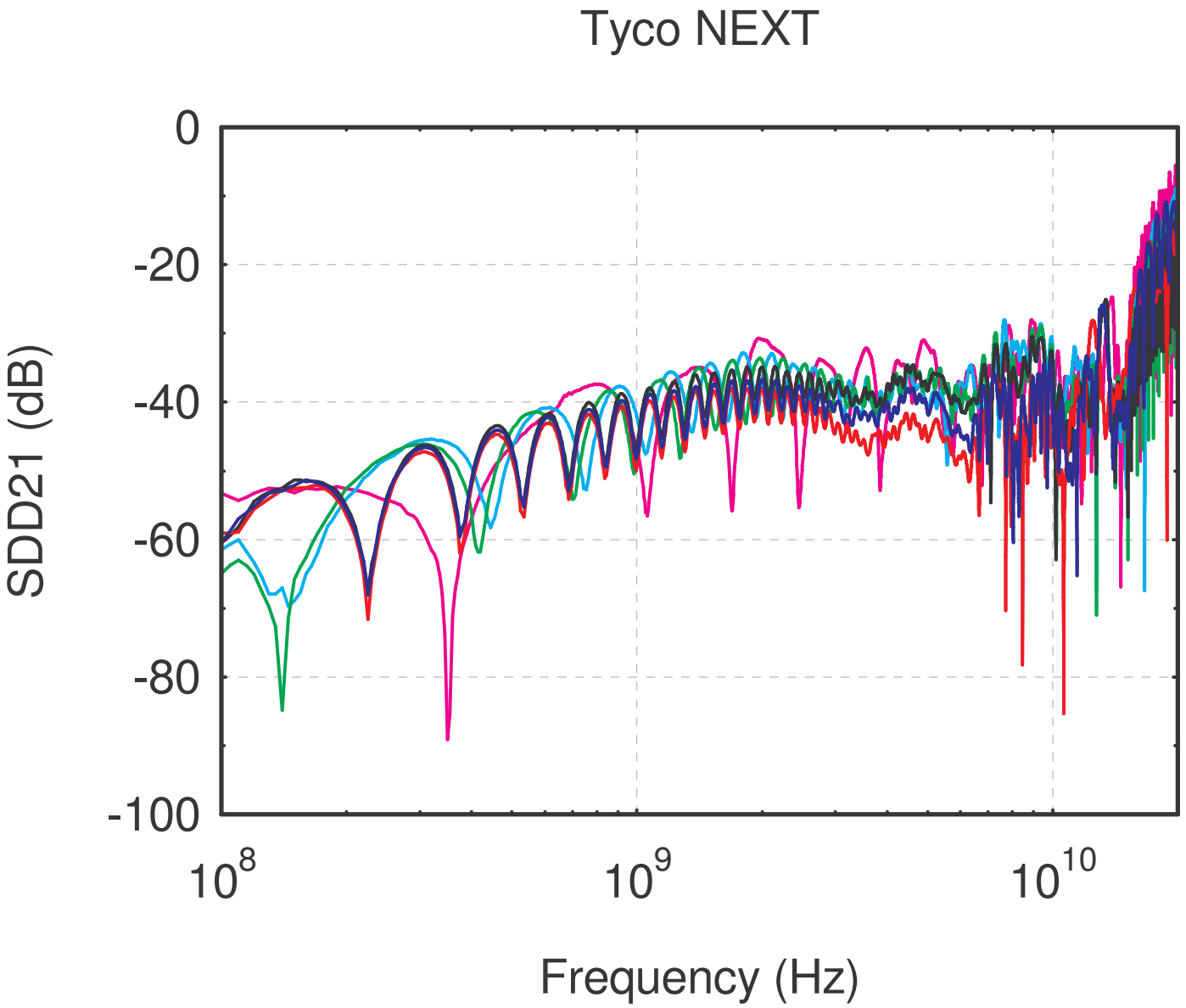
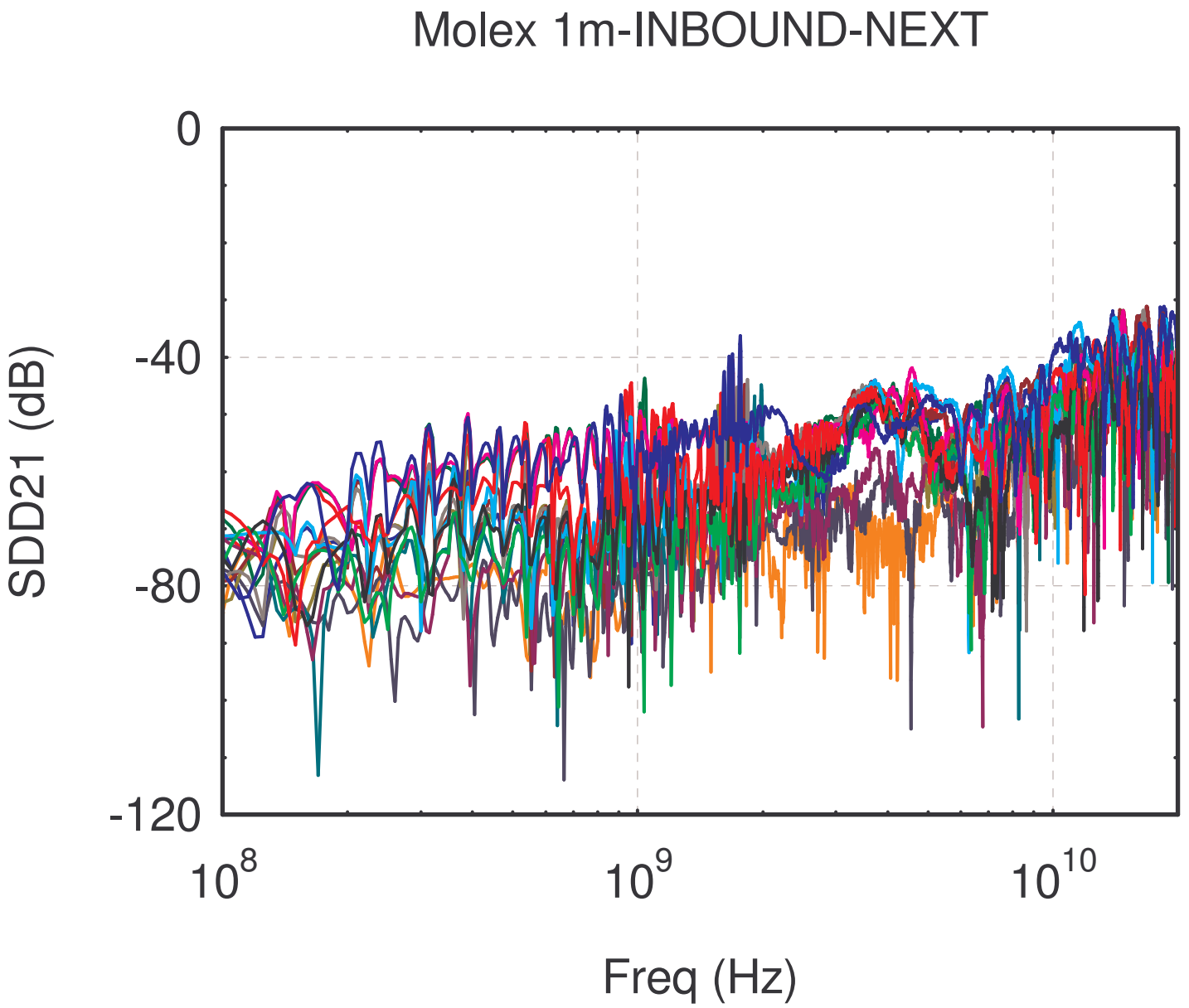
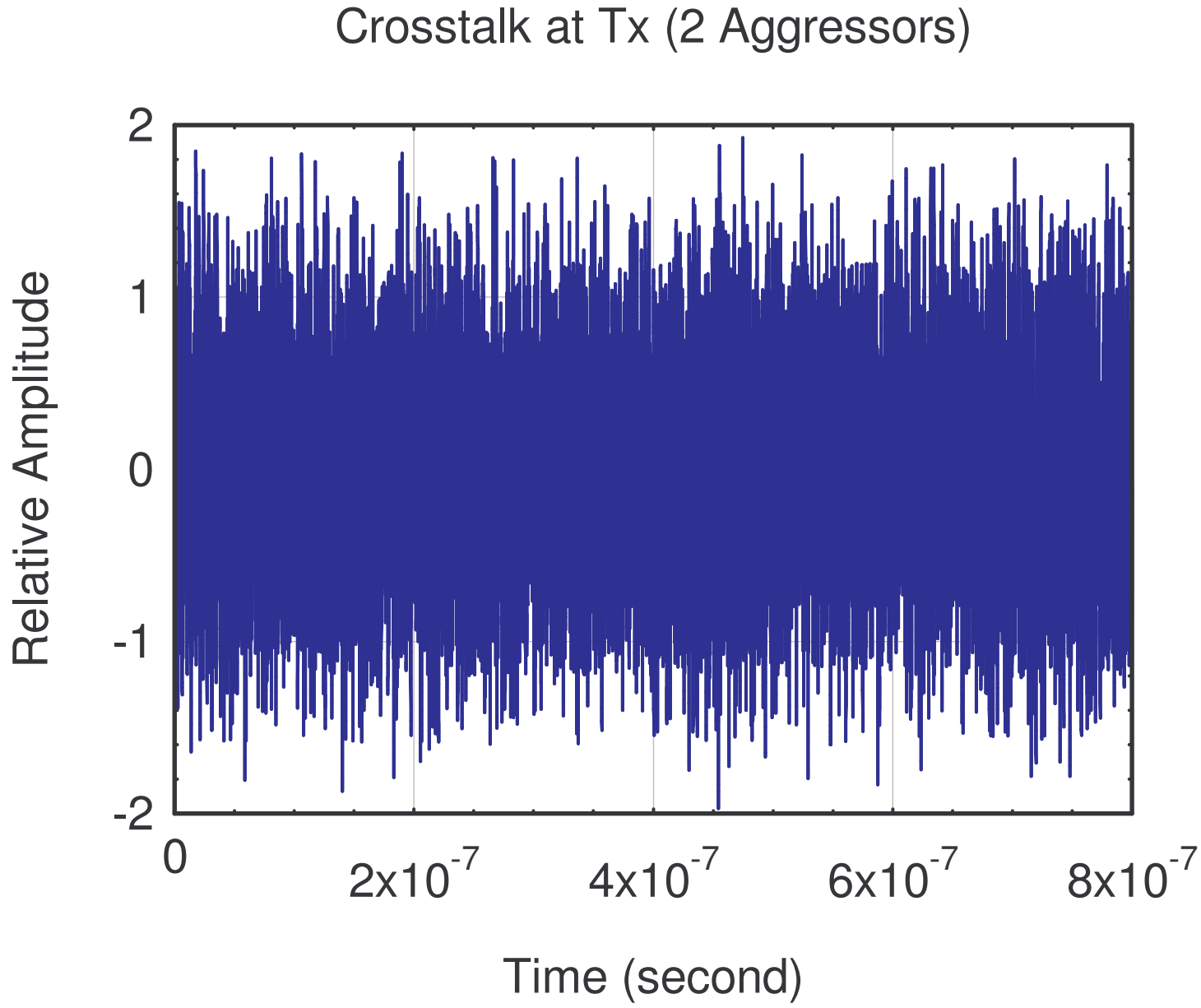
-25
-50
-75
-100
-125
SDD21 (dB)
10^8
10^9
10^10
Frequency (Hz)

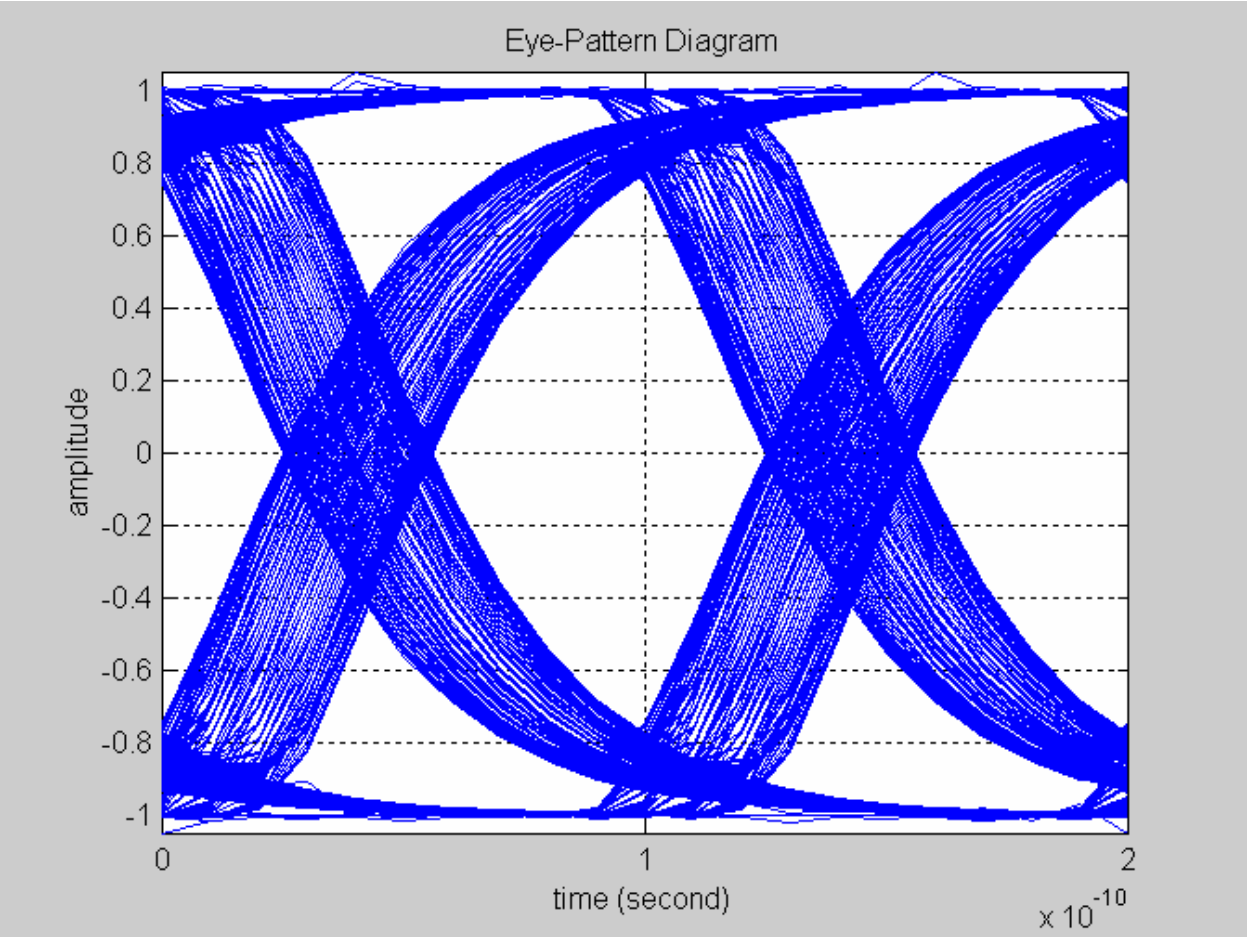

Worst 3 Intel NEXT
0
-25
-50
-75
-100
-125
SDD21 (dB)
10^8
10^9
10^10
Frequency (Hz)


Tyco NEXT
0
-20
-40
-60
-80
-100
SDD21 (dB)
10^8
10^9
10^10
Frequency (Hz)


Molex 1m-INBOUND-NEXT
0
-40
-80
-120
SDD21 (dB)
10^8
10^9
10^10
Freq (Hz)

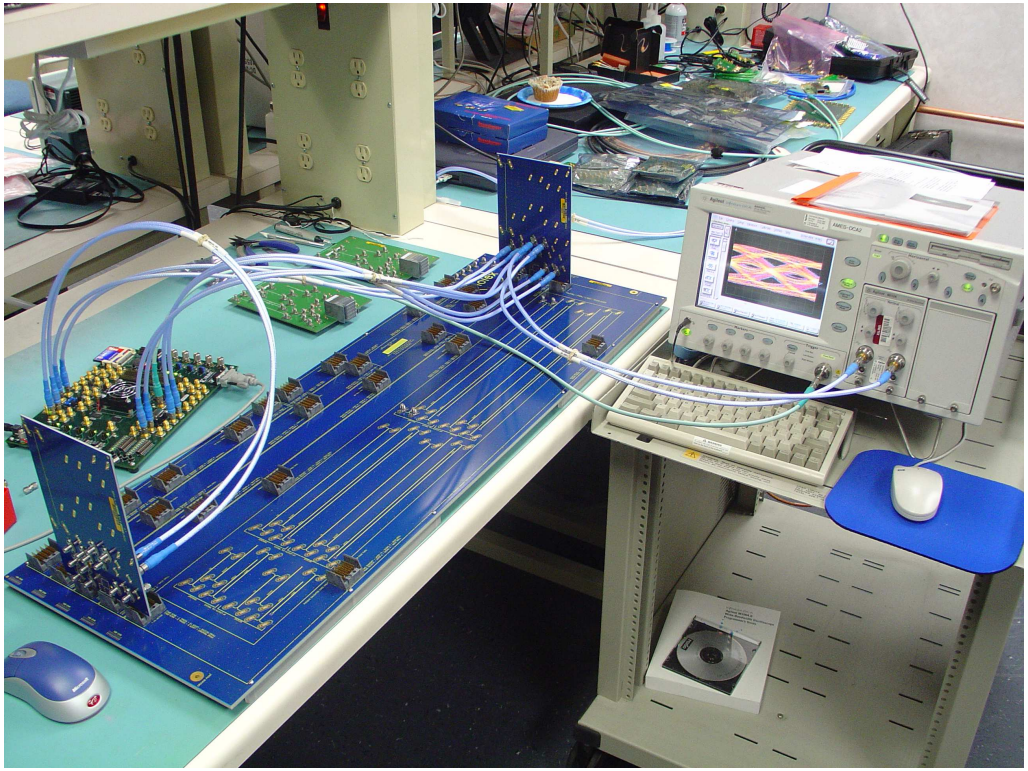

Crosstalk at Tx (2 Aggressors)
Relative Amplitude
2
1
0
-1
-2
0
2x10-7
4x10-7
6x10-7
8x10-7
Time (second)

Tx Signal Showing Jitter and 7.5 GHz Effect



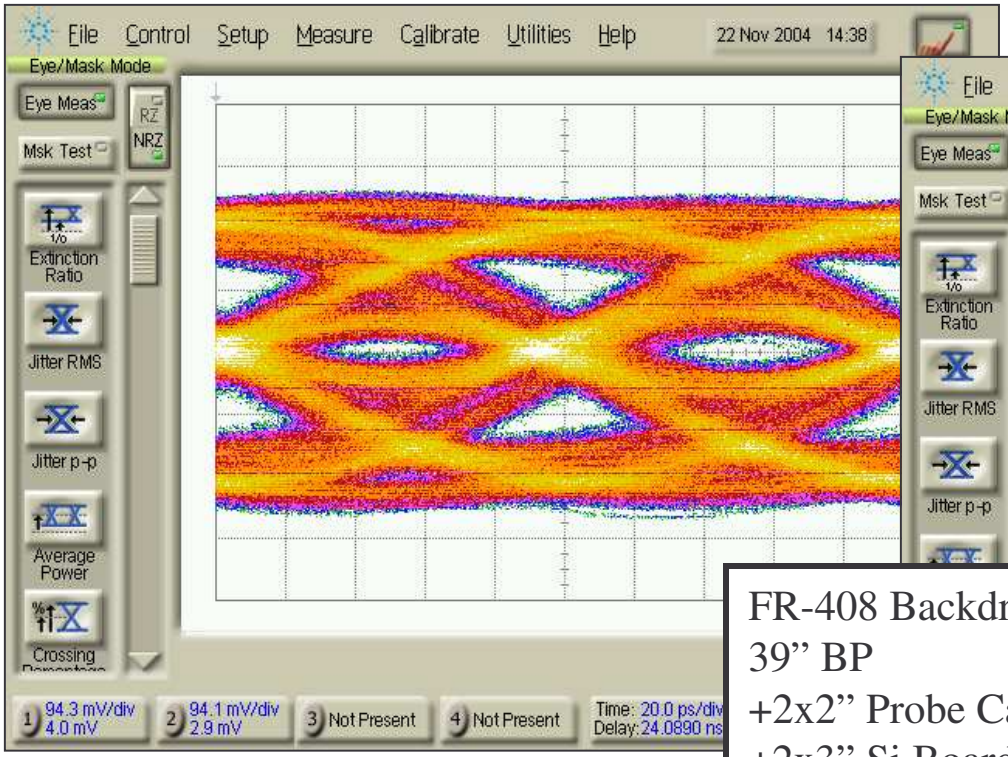
Molex Concept Backplane

- Molex GBX connectors
- ISOLA FR-408 material
- 225 mil thick

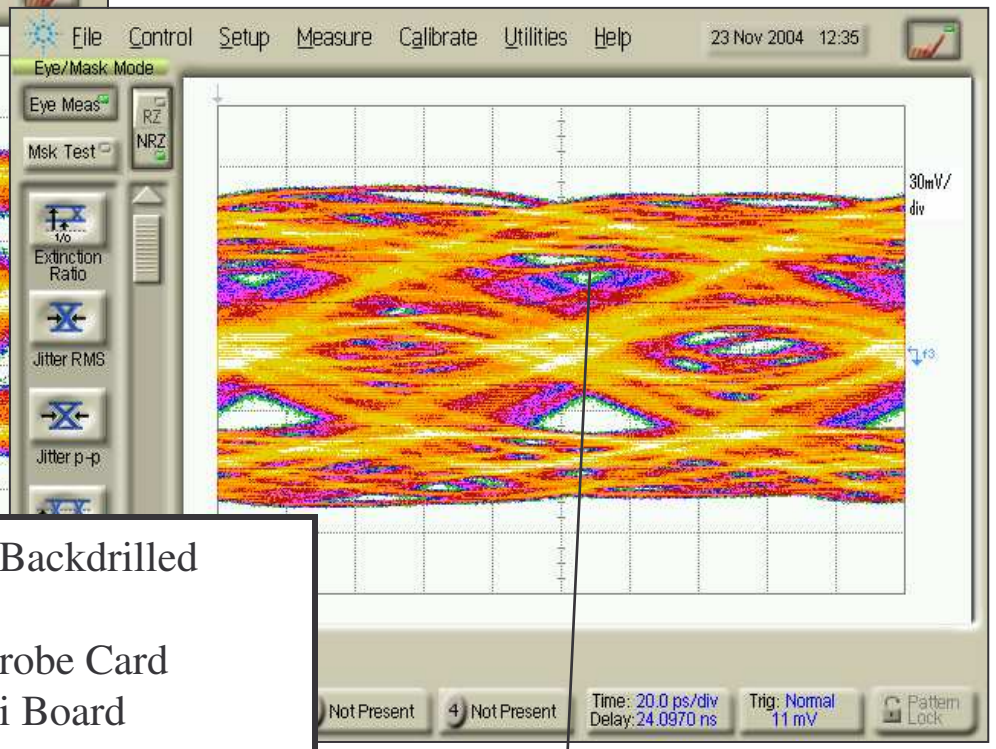


- Total signal path
  = 39” BP + 2x2” LC + 2x3” FPGA Bd
  = 50 inches on FR-408

Molex Backplane and Xilinx FPGA
10Gbps NRZ Waveform before Rx Eq



Without Crosstalk



With NEXT Crosstalk driven

FR-408 Backdrilled
39" BP
+2x2" Probe Card
+2x3" Si Board
=50 inches
BER<10^13
Crosstalk shown (right)

Note how Crosstalk disturbs the DB Eye
NRZ Rx still receives signal