The Effect of Inserted ISI on Transition Density Plots and DCD & ISI Histograms of MJS Patterns

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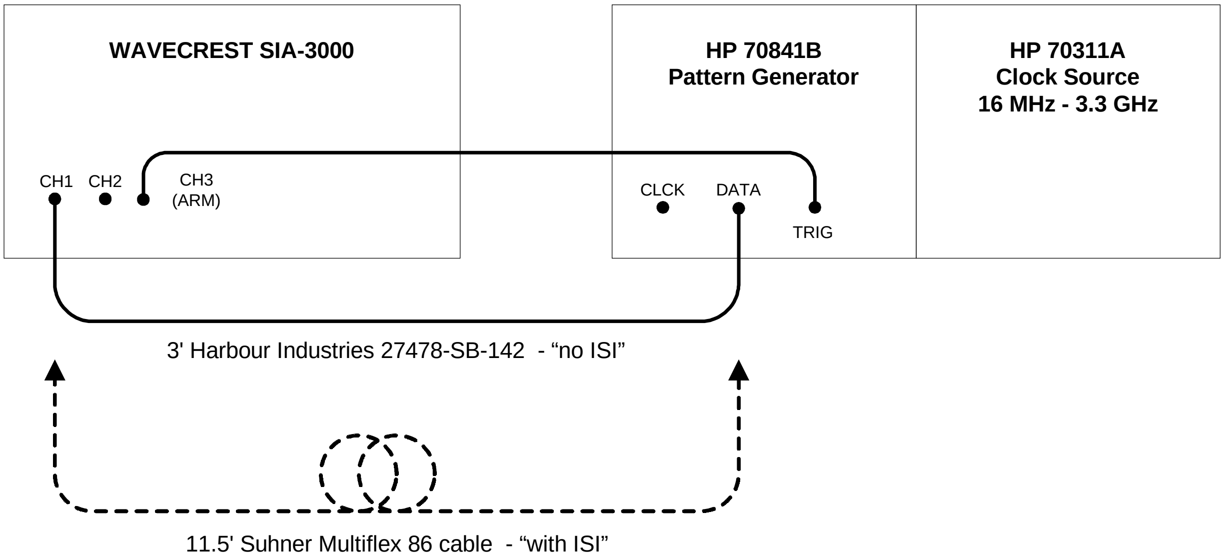
I. INTRODUCTION

The purpose of this technical report is to document the effect of adding Inter-Symbol Interference (ISI) to FC-MJS K28.5, IDLE, CRPAT, and CJTPAT patterns. ISI was added by using a relatively 11.5 foot RF cable in place of a 3 foot RF cable. Data was acquired with the short cable for the data signal (“no ISI”) and then again with the long cable in place on the data signal (“with ISI”).

Duty Cycle Distortion (DCD) and ISI as a function of edge position within the pattern (transition density plot) were acquired for each of these four FC-MJS patterns, with and without ISI added. Histograms showing DCD and ISI on rising and falling edges were also acquired. All plots were acquired using the Known Pattern with Marker mode on the Wavecrest SIA-3000.

II. EQUIPMENT SETUP

For this study, a Wavecrest SIA-3000 was used to acquire the data, and a HP 70841B Pattern Generator with 3.3GHz HP 70311A Clock Source was used a stimulus as shown here.



Cable hookup was single-ended only for all signals. For "no ISI" trials, a 3 ft. Harbour Industries cable was used on both data and arm inputs to the SIA-3000. For the "with ISI" trials, a 11.5 ft. Suhner cable replaced the 3 ft. data cable and the acquisition was repeated. "Virtual Instruments Signal Integrity™"(VISI) rev 7.2.1 software was loaded on the SIA-3000 for all measurements taken for this study.

The clock source for the HP 70841B was set to 2.125Gbps for all measurements. The Amplitude and High Level for the data output of the HP 70841B were set to 800 mV. The Trigger of the pattern generator was used as an arm for the SIA-3000 operating in *Known Pattern with Marker* mode. A cut-off frequency of 1274kHz was used for all filter settings. Setup of the SIA-3000 is as follows:

- Select *Known Pattern with Marker* mode from *dataCOM tools* menu on the SIA-3000.
- Set cutoff frequency to be 1274 kHz under *Acquire Options* side menu.
- Default settings used on *Bit Rate Setup* on the SIA-3000.
- Default settings used n *DCD+ISI Setup*, except under *Filter Options*, the LPF and HPF were enabled with corner frequencies of 1274 kHz.
- Default settings used for *RJ+PJ Options*, with Tailfit set to Auto and both RJ and PJ filters were enabled as Brick Wall filters with 1274 kHz cutoff.
- Default settings used under *Voltages* side menu.

For the CJTPAT pattern, the acquired data was processed with and without the DCD+ISI filter enabled in Wavecrest VISI software. With the DCD+ISI HPF enabled, modeling of receiver clock recovery performance with this jitter tolerance pattern can be obtained and compared to that with the DCD+ISI filter disabled, which is similar to comparing to a reference bit clock.

III. TEST PROCEDURE

This study of the effects of inserted ISI on FC-MJS patterns was split into two parts and followed this general test procedure:

For each of the K28.5, IDLE, CRPAT, and CJTPAT patterns, perform the following:

- Setup equipment to acquire measurements as in the previous section using 3' cable for the data signal.
- Load the appropriate pattern into HP Pattern Generator and on the SIA-3000 using the *Pattern Options* side menu.
- Conduct *Perform Placement* of marker under the *Arm Setup* side menu on the SIA-3000.
- Press *Single/Stop* to perform data acquisition for "no ISI" case.
- Save acquired data and VISI settings under *Tool*, *Save As* menu options.
- Replace 3' cable with 11.5' cable for data signal.
- Conduct *Perform Placement* of marker under the *Arm Setup* side menu on the SIA-3000.
- Clear screen of previous data.
- Press *Single/Stop* to perform data acquisition for "with ISI" case.
- Save acquired data and VISI settings under *Tool*, *Save As* menu options.

IV. TEST RESULTS SUMMARY

A summary of the test results is shown in Table 1. below, with results reported in both unit interval and picoseconds of jitter. A delta in the DCD+ISI and in the TJ was computed in each case to quantify the increase in jitter when the long cable was used to purposely introduce ISI.

Table 1. Summary of Results

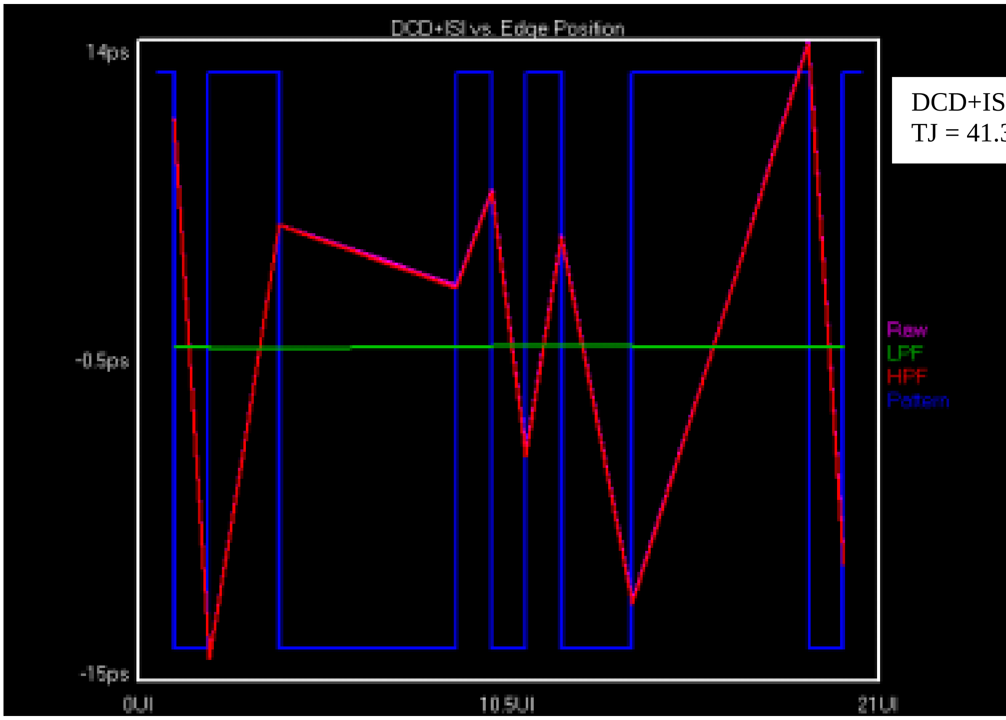
		in Unit Interval (UI)			in picoseconds (ps)		
Pattern	**Parameter**	**Without ISI**	**With ISI**	**Delta**	**Without ISI**	**With ISI**	**Delta**
K28.5	DCD+ISI	0.0591	0.0932	0.0341	27.796	43.880	16.084
	TJ	0.0878	0.1271	0.0393	41.342	59.830	18.488
IDLE	DCD+ISI	0.0721	0.0942	0.0221	33.909	44.343	10.434
	TJ	0.1034	0.1265	0.0231	48.665	59.538	10.873
CRPAT	DCD+ISI	0.0810	0.1098	0.0288	38.117	51.657	13.54
	TJ	0.1095	0.1438	0.0343	51.527	67.676	16.149
CJTPAT (HPF On)	DCD+ISI	0.0822	0.1254	0.0432	38.694	59.021	20.327
	TJ	0.1090	0.1569	0.0479	51.285	73.840	22.555
CJTPAT (HPF Off)	DCD+ISI	0.0753	0.1025	0.0272	35.425	48.234	12.809
	TJ	0.1023	0.1344	0.0321	48.156	63.244	15.088
CJTPAT HPF On-Off Delta	DCD+ISI	0.0069	0.0229	0.0160	3.269	10.787	7.518
	TJ	0.0066	0.0225	0.0159	3.129	10.596	7.467

For every pattern, ISI increased by 10 ps to 20 ps with the replacement of the short cable with the long cable, depending on the pattern. The CJTPAT pattern with HPF "On" had the highest absolute DCD+ISI and also produced the highest relative change in DCD+ISI, all other conditions being the same. Comparing "with ISI" to "without ISI" cases of CJTPAT HPF On-Off Deltas at the bottom of the table shows a significantly higher DCD+ISI for the "with ISI" case when the DCD+ISI HPF is On.

In the following sections, transition density plots show a general increase in the variation of the mean DCD+ISI at each edge location, and DCD+ISI histograms also show broadening with the insertion of the long cable, as expected. Note that the Y-scales of the transition density plots in the next section are different.

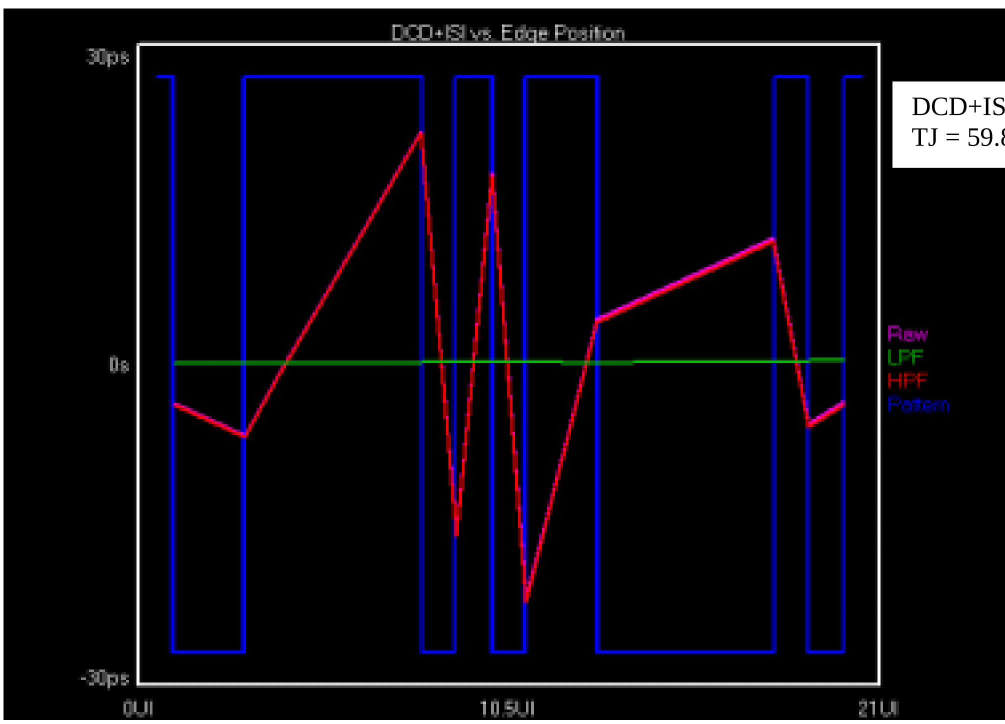
The zoomed-in comparison plots of the CJTPAT pattern in Appendix A of the "no ISI" case versus "with ISI case" focus on three areas which have significant transition density changes. The Y-scale of the plots in Appendix A were matched as close as possible, while the X axis was shifted by approximately 20 UI for the "with ISI" case due to the phase difference with the long cable.

V. TEST RESULTS: TRANSITION DENSITY PLOTS



DCD+ISI = 27.796 ps
TJ = 41.342 ps

Fig. 1, K28.5 Pattern, Without ISI

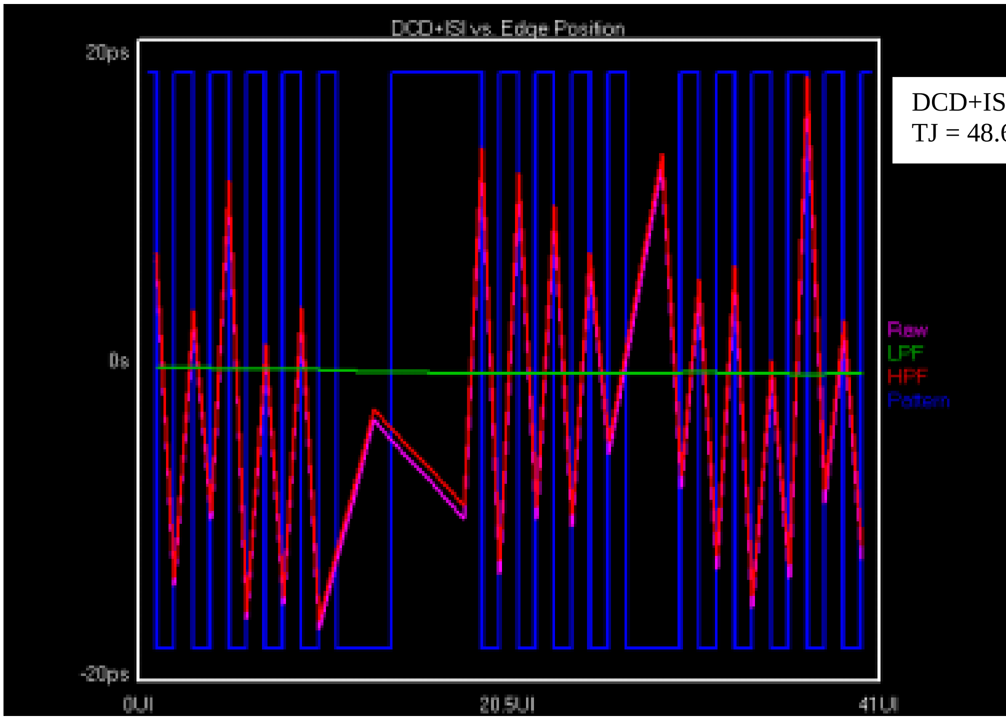


DCD+ISI = 43.880 ps
TJ = 59.830 ps

Fig. 2, K28.5 Pattern, With ISI

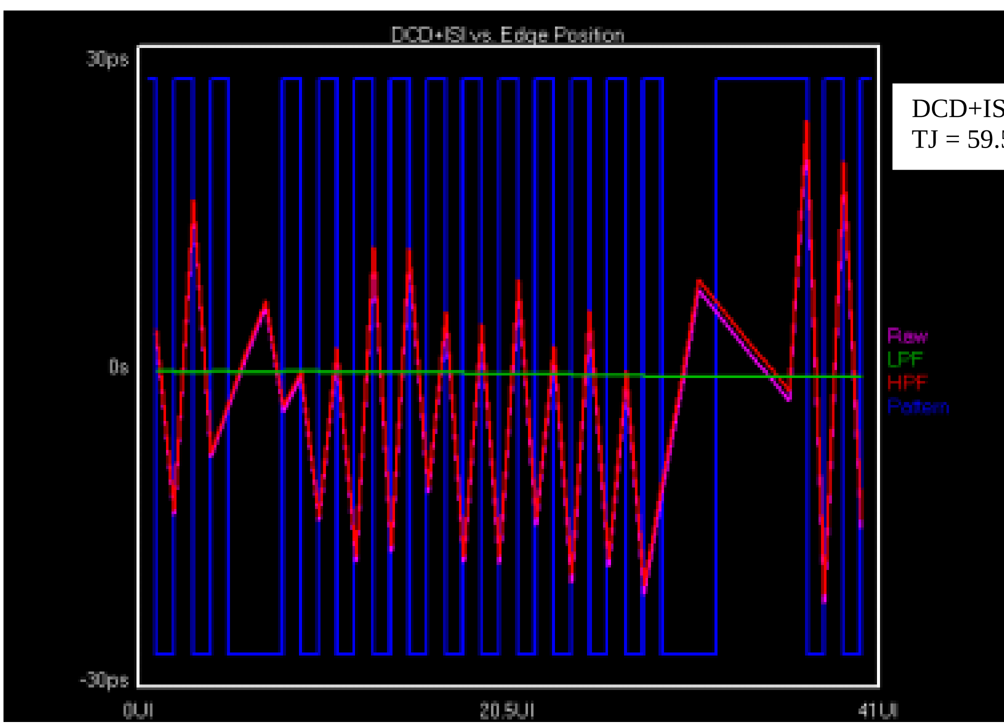
With vs. Without ISI Delta for IDLE
Δ DCD+ISI = 16.084 ps, Δ TJ = 18.488 ps

V. TEST RESULTS: TRANSITION DENSITY PLOTS (cont.)



DCD+ISI = 33.909 ps
TJ = 48.665 ps

Fig. 3, IDLE Pattern, Without ISI

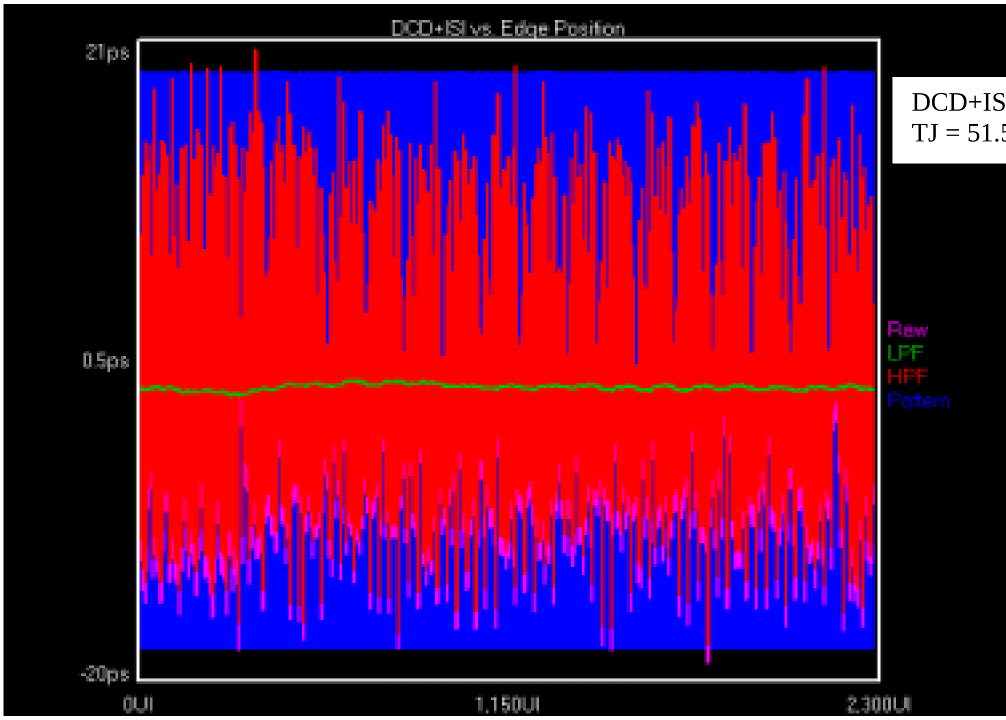


DCD+ISI = 44.343 ps
TJ = 59.538 ps

Fig. 4, IDLE Pattern, With ISI

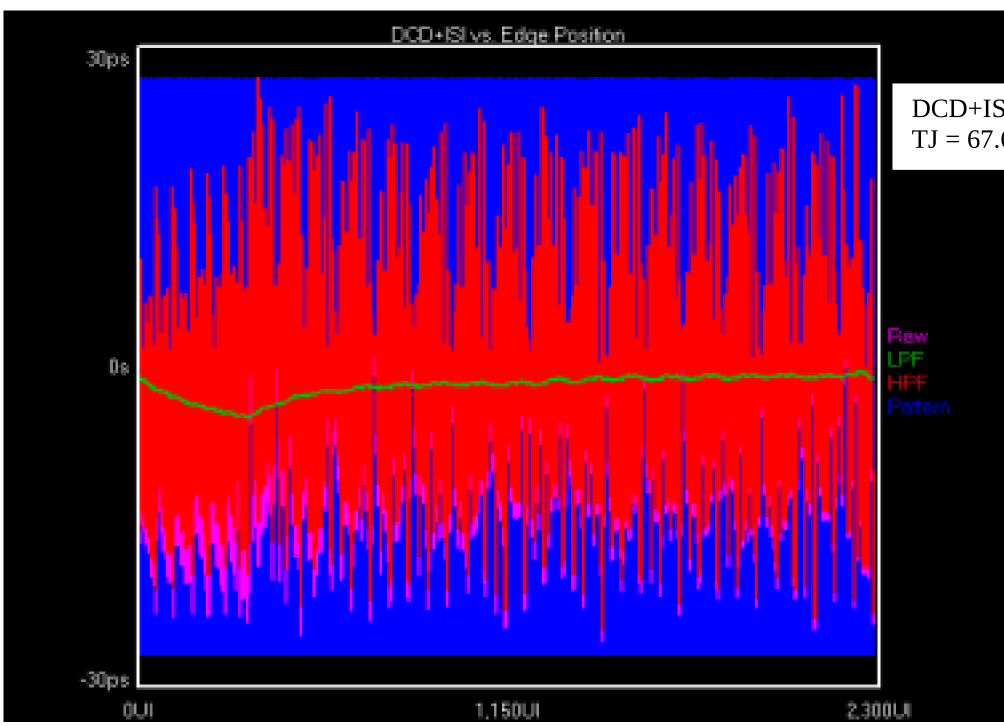
With vs. Without ISI Delta for IDLE
Δ DCD+ISI = 10.434 ps, Δ TJ = 10.873 ps

V. TEST RESULTS: TRANSITION DENSITY PLOTS (cont.)



DCD+ISI = 38.117 ps
TJ = 51.527 ps

Fig. 5, CRPAT Pattern, Without ISI



DCD+ISI = 51.657 ps
TJ = 67.676 ps

Fig. 6, CRPAT Pattern, With ISI

With vs. Without ISI Delta for CRPAT
Δ DCD+ISI = 13.540 ps, Δ TJ = 16.149 ps

V. TEST RESULTS: TRANSITION DENSITY PLOTS (cont.)

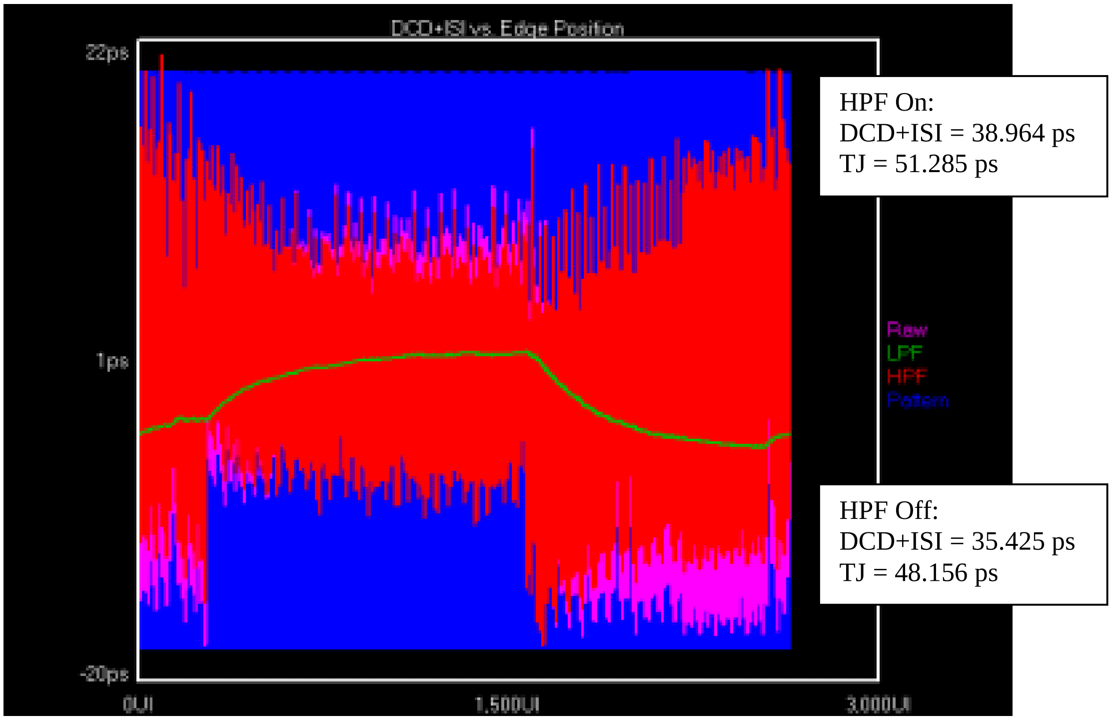


Fig. 7, CJTPAT Pattern, Without ISI

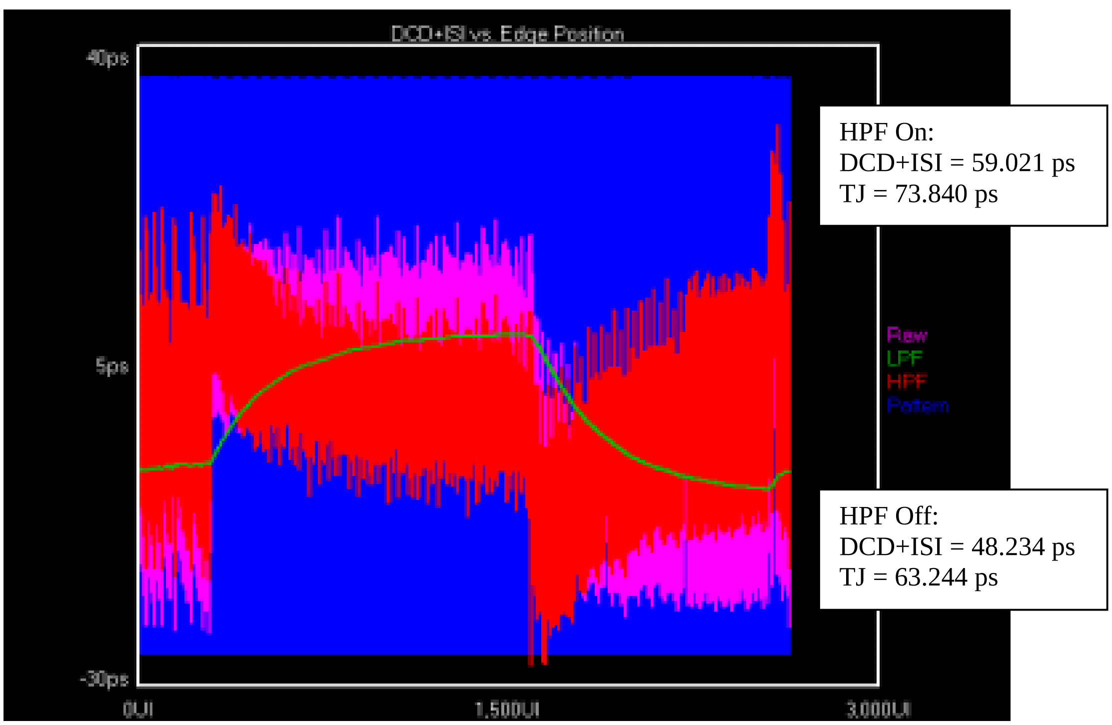
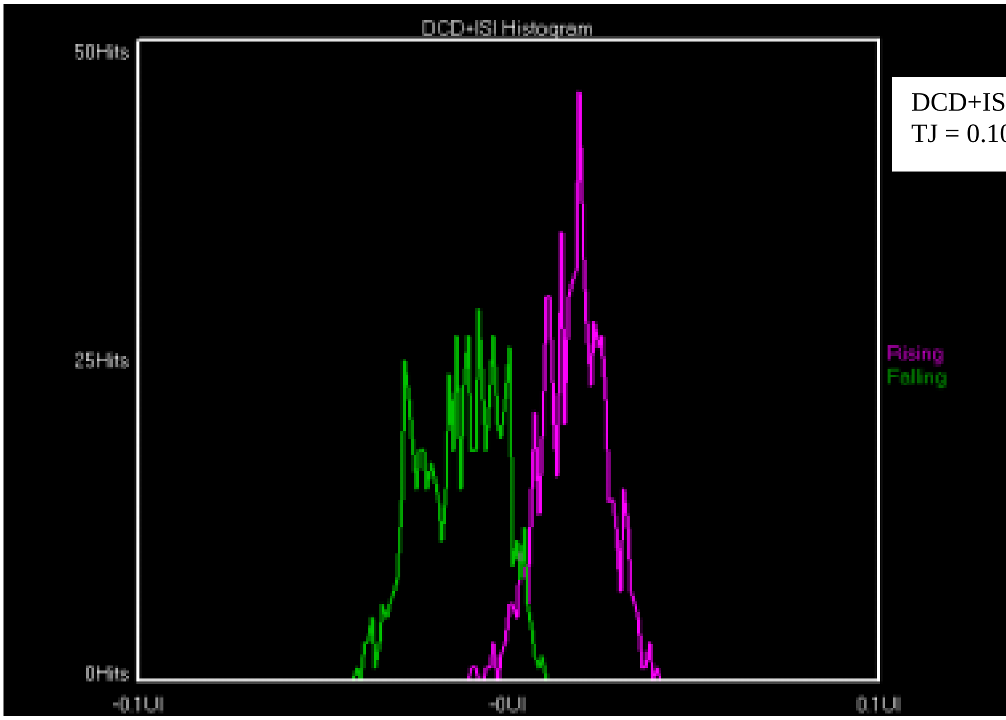


Fig. 8, CJTPAT Pattern, With ISI

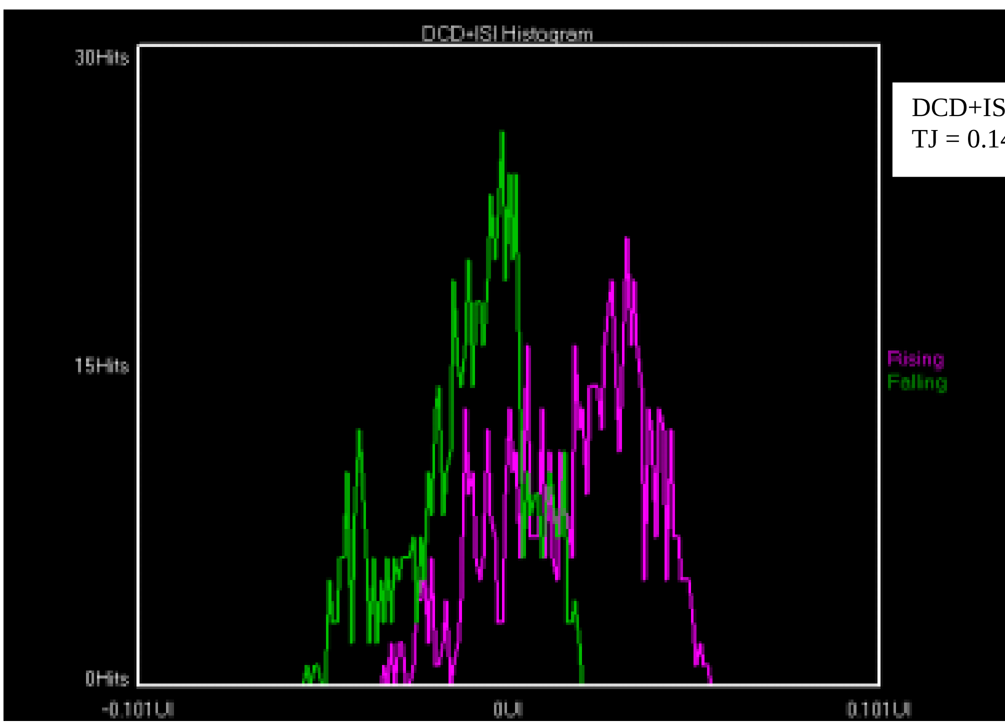
With vs. Without ISI Delta for K28.5
HPF On: Δ DCD+ISI = 20.327 ps, Δ TJ = 22.555 ps
HPF Off: Δ DCD+ISI = 12.809 ps, Δ TJ = 15.088 ps

VI. TEST RESULTS: DCD + ISI HISTOGRAMS



DCD+ISI = 0.0810 UI
TJ = 0.1095UI

Fig. 9, CRPAT Pattern, Without ISI

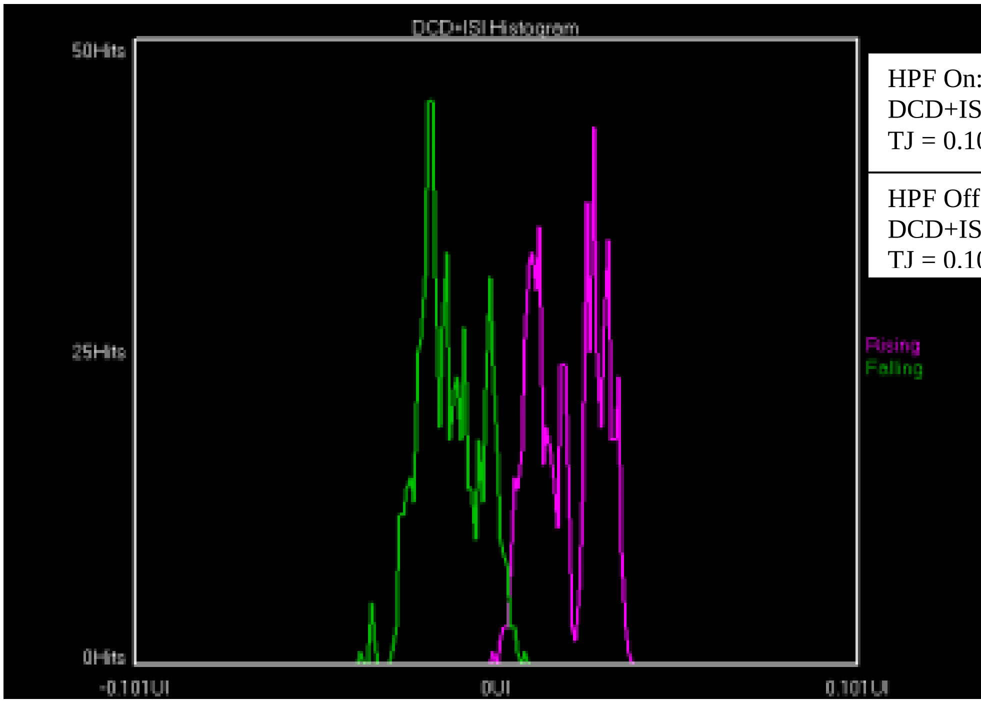


DCD+ISI = 0.1098 UI
TJ = 0.1438 UI

Fig. 10, CRPAT Pattern, With ISI

With vs. Without ISI Delta for CRPAT
Δ DCD+ISI = 0.0288 UI, Δ TJ = 0.0343 UI

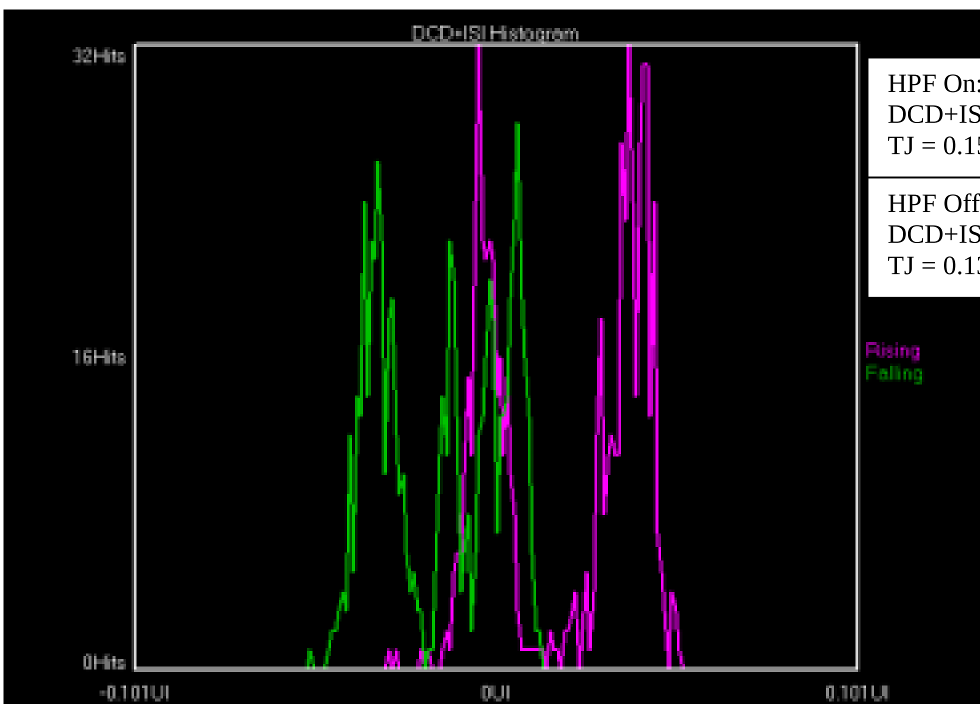
VI. TEST RESULTS: DCD + ISI HISTOGRAMS (cont.)



HPF On:
DCD+ISI = 0.0822 UI
TJ = 0.1090UI

HPF Off:
DCD+ISI = 0.0753 UI
TJ = 0.1023 UI

Fig. 11, CJTPAT Pattern, Without ISI



HPF On:
DCD+ISI = 0.1254 UI
TJ = 0.1569 UI

HPF Off:
DCD+ISI = 0.1025 UI
TJ = 0.1344 UI

Fig. 12, CJTPAT Pattern, With ISI

With vs. Without ISI Delta for CJTPAT
HPF On: Δ DCD+ISI = 0.0432 UI Δ TJ = 0.0479 UI
HPF Off: Δ DCD+ISI = 0.0272 UI. Δ TJ = 0.0321 UI

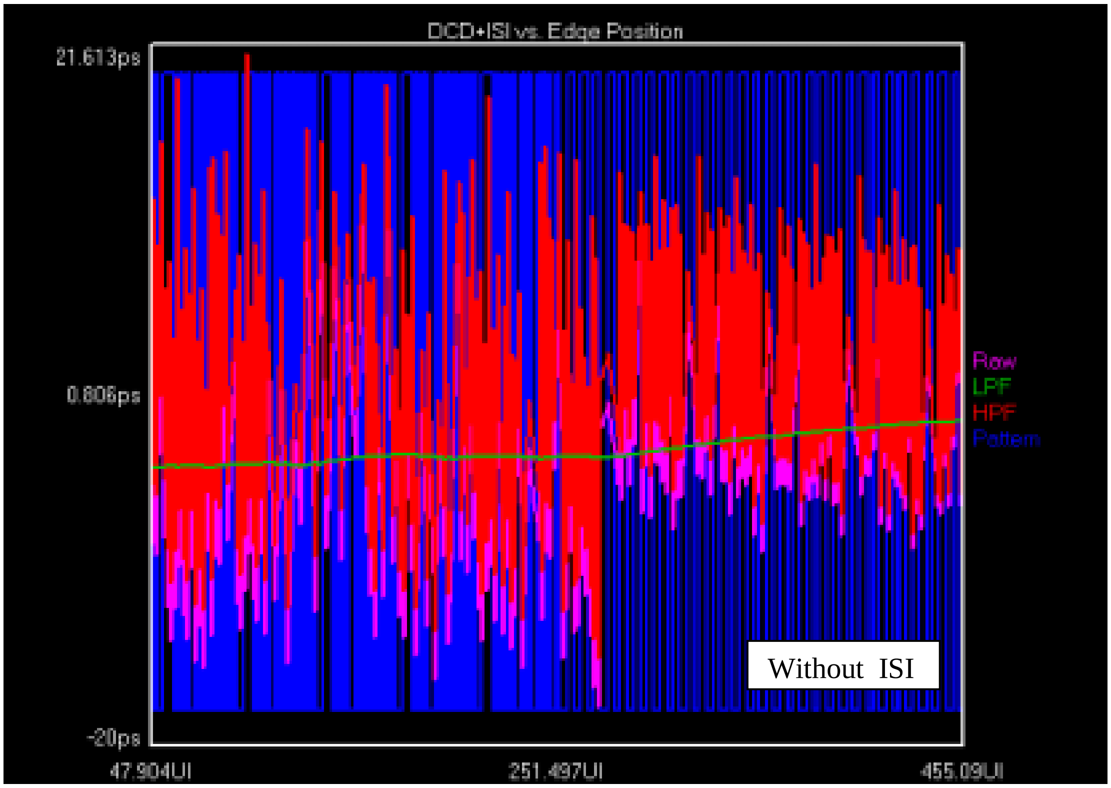
VII. CONCLUSIONS

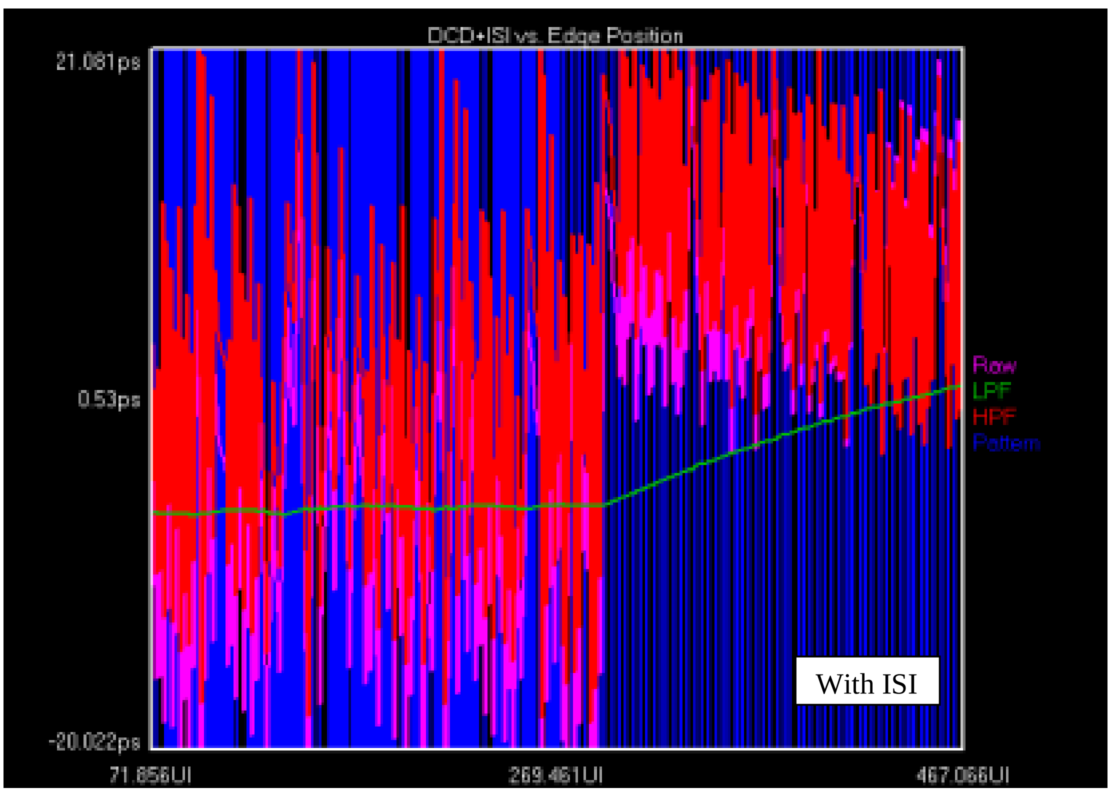
The transition density plot for every pattern showed a significant increase in DCD+ISI with the insertion of a long cable in place of a short cable, as expected. The results can also be seen in a widening of the DCD+ISI histograms. Increased DCD+ISI when using the long cable manifests itself in two ways: most edges have more extreme DCD+ISI averages given a steady transition density, and greater excursions of the mean DCD+ISI for a shift in the average transition density. This can be best observed by comparing excursions of the LPF or HPF lines on the transition density plots for the with/without ISI cases of long patterns CRPAT or CJTPAT. This is easiest to observe in the zoomed transition density plots of CJTPAT in Appendix A.

In the special case of comparing DCD+ISI HPF "On" versus "Off" for CJTPAT, DCD+ISI increased 0.0229 UI with the HPF "On" for the long cable, but increased 0.0069 UI with the HPF "On" for the short cable. Since enabling the DCD+ISI HPF models the performance of a recovered clock, this sensitivity to introduced ISI implies that a recovered clock will also exhibit this performance under similar conditions.

APPENDIX A

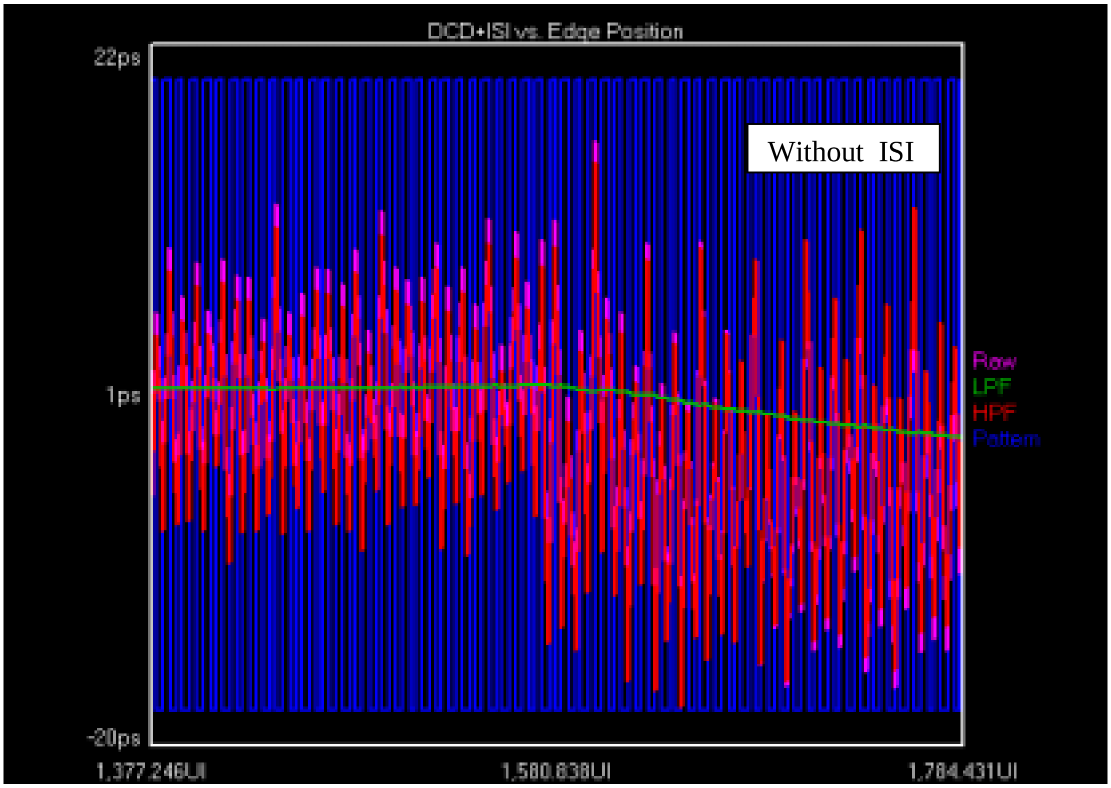
DETAILED CJTPAT TRANSITION DENSITY PLOT COMPARISON

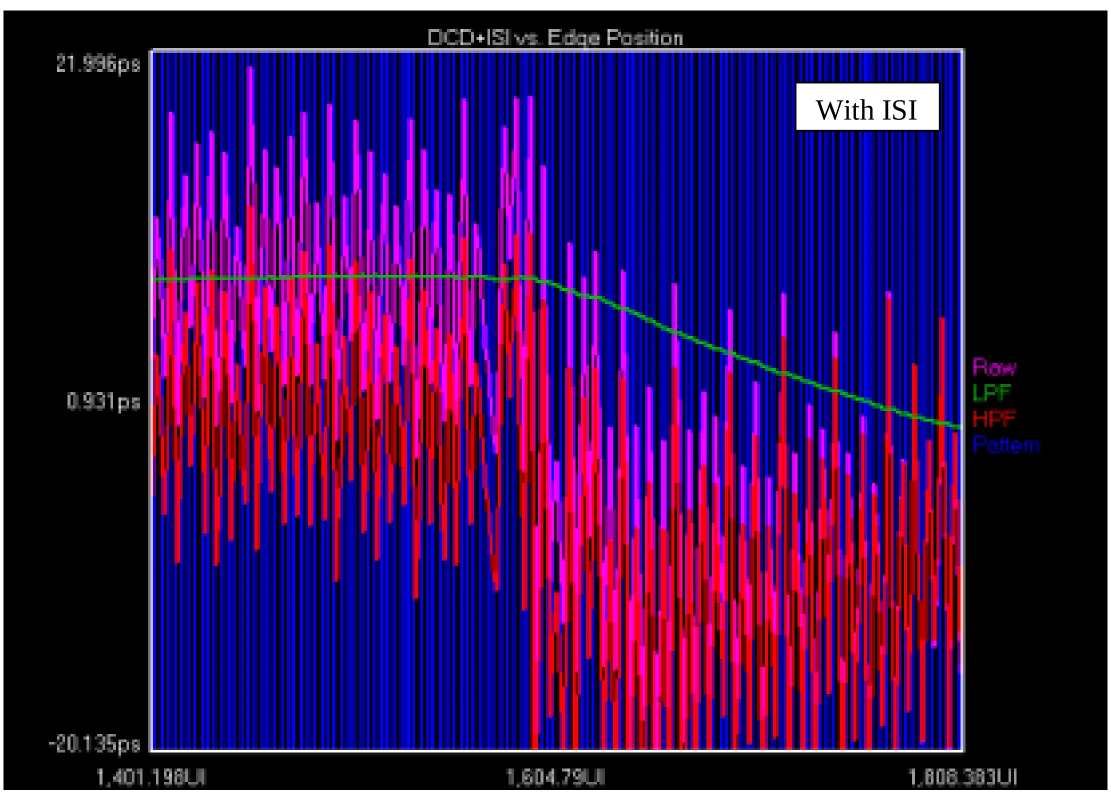




APPENDIX A

DETAILED CJTPAT TRANSITION DENSITY PLOT COMPARISON (cont.)





APPENDIX A

DETAILED CJTPAT TRANSITION DENSITY PLOT COMPARISON (cont.)