Application Report
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Signal Integrity Versus Data Rate and Cable Length for RS-485 Transceivers

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ABSTRACT

This document contains lab data for THVD1450 and THVD1429 RS-485 transceivers operating over a range of different cable lengths and data rates. Jitter measurements are provided for a variety of test combinations between 1 m to 1 km and 100 kbps to 50 Mbps (depending on the device being tested).

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Trademarks

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1 Introduction

The THVD14xx family of transceivers has been designed to work in a range of applications, facilitating the transfer of data over relatively long distances while maintaining immunity against the electromagnetic noise present in many industrial applications. Different variants within this family can be selected based on particular applications needs ranging from different pin outs, half/full-duplex, data rates, loading characteristics, ESD protections and more. All devices in this family can work with supply voltages between 3.0 and 5.5 volts.

All of these devices operate within the standard set by TIA and EIA for RS-485 transceivers which specifies features such as signal amplitude, input sensitivity, and input impedance. However, several characteristics such as cable length, cable type, connectors, data rates, and bus topologies are not defined by the standard. This document's purpose is to provide a reference to tests in a controlled environment to help system designers understand how the factors of cable length and data rate can affect data integrity and provide insight so educated design decisions can be made.

Two devices were used in this series of tests. The THVD1450 is a high speed variant which supports data rates up to 50 Mbps. The THVD1429 has similar operating characteristics to the THVD1450 with the notable inclusion of an integrated TVS diode for increased ESD protection. This TVS diode adds some amount of capacitance for each node and therefore is only specified to operate at data rates up to 20 Mbps. These two devices were tested and the results compared to observe the effect that added loading on the bus can have on the capabilities of the system.

2 Jitter

The amount of jitter present in a system is a good indication of data integrity through a cable. Many factors contribute to the amount of jitter in a system. The two variables that this document will focus on are cable length and data rate. More on jitter and how it can be measured can be found in the application note for Signal Integrity vs. Transmission Rate and Cable Length for RS-485 Transceivers (SLLA375).

3 Measurement Setup

The test setup included a PRBS generator configured to output random data at a configurable data rate. The output of the generator was connected to a RS-485 half-duplex EVM. The device mounted on this board had its driver enabled and receiver disabled. The outputs of the driver device were connected to different spools of unshielded twisted-pair cables (Belden 3105A) of varying lengths. The other end of the spool was connected to a second RS-485 half-duplex EVM which had its receiver enabled and driver disabled. Both boards used 120-Ohm termination near the transceiver. The bus lines (A and B) on the receiver board were connected to an oscilloscope using two 1-MΩ, < 10 pF probes configured as a differential pair. The R pin of the receiver device was also connected directly to an oscilloscope channel configured for 50-Ω termination. Lastly, the oscilloscope was connected to the trigger output of the PRBS generator using a 50-cm cable and was set to trigger on this input.

To conduct the test, same-model devices (THVD1450s or THVD1429s) were populated on the transmitter and receiver side of the setup. A cable length was selected and connected to both boards. The PRBS generator was configured to output data at a given data rate and the results were viewed on the oscilloscope. To measure jitter, the oscilloscope was set to infinite persistence. Using a histogram, the peak-to-peak variation of the horizontal crossing point of the resulting differential eye diagram was recorded; the results of this measurement are referred to as “Differential Jitter” in this document. Using the cursors lined up at the first and last transition in the persistent figure, the jitter of the single output line was measured and recorded; this is referred to as “Output Jitter” in this document.

The data rate of the PRBS signal was increased until it reached the device’s specified limit or the methods of measurement could not differentiate different bit periods (past 80% jitter). At this point, a new cable length was connected. This series of tests was done for the THVD1450 and THVD1429. Both devices were supplied 5.0 V to VCC and a common ground was used by both transmitter and receiver.

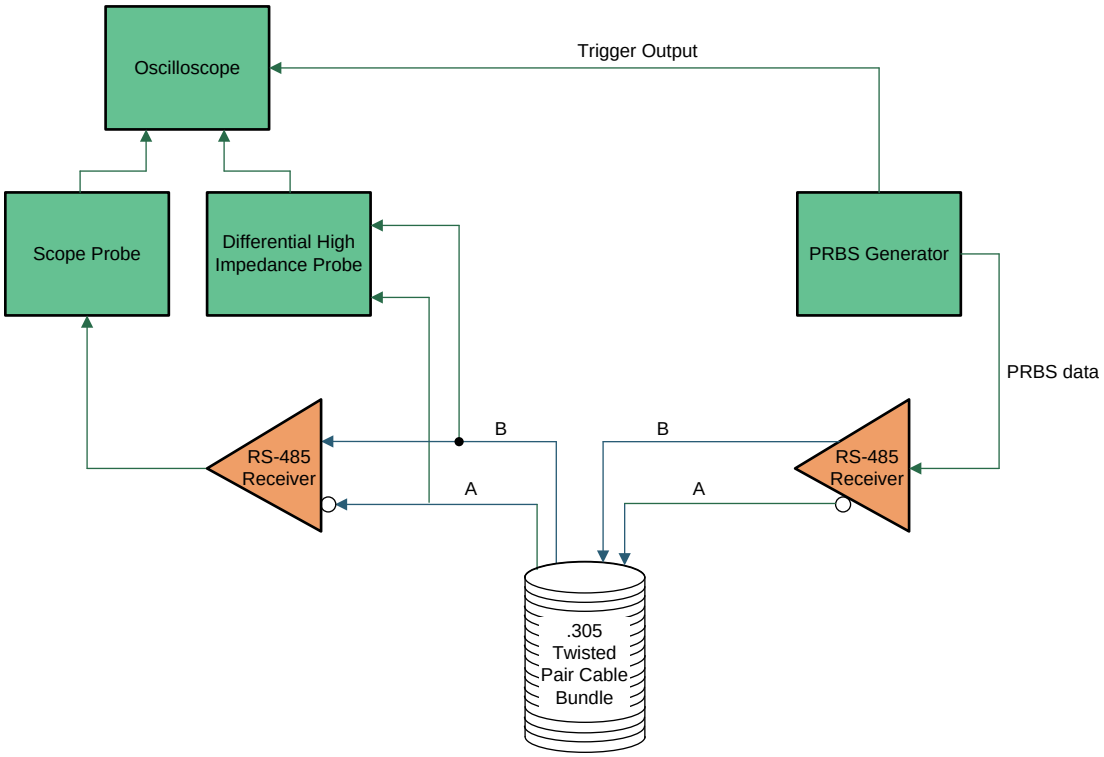

Figure 1. Jitter Measurement Set-Up

4 Lab Results

Table 1. THVD1450 Jitter Test Results

Cable Length (m)	Data Rate (Mbps)	Bit Duration (ns)	Differential Jitter (ns)	Eye Width (ns)	Total Differential Jitter	Output Jitter (ns)	Eye Width (ns)	Total Output Jitter[1]
1	1	1000.0	0.4	999.6	0%	3.2	996.8	0%
1	10	100.0	0.6	99.4	1%	3.1	96.9	3%
1	20	50.0	0.9	49.1	2%	3.1	46.9	6%
1	30	33.3	1.1	32.2	3%	3.2	30.1	10%
1	40	25.0	1.3	23.7	5%	3.8	21.2	15%
1	50	20.0	1.6	18.4	8%	4.2	15.8	21%

(1) The level of acceptable jitter in a given application would be dependent on the overall serial communications system implementation. Most systems can tolerate around 20% without a substantial increase in bit error rate, and some may tolerate jitter levels as high as 50%.

Table 1. THVD1450 Jitter Test Results (continued)

Cable Length (m)	Data Rate (Mbps)	Bit Duration (ns)	Differential Jitter (ns)	Eye Width (ns)	Total Differential Jitter	Output Jitter (ns)	Eye Width (ns)	Total Output Jitter[1]
50	1	1000.0	3.2	996.8	0%	2.6	997.4	0%
50	2	500.0	3.5	496.5	1%	3.4	496.6	1%
50	4	250.0	4.0	246.0	2%	3.6	246.4	1%
50	10	100.0	4.2	95.8	4%	3.7	96.3	4%
50	12	83.3	9.1	74.2	11%	5.0	78.3	6%
50	14	71.4	10.2	61.2	14%	6.7	64.7	9%
50	16	62.5	9.8	52.7	16%	5.9	56.6	9%
50	18	55.6	8.0	47.6	14%	4.8	50.8	9%
50	20	50.0	9.1	40.9	18%	5.5	44.5	11%
50	22	45.5	7.5	38.0	17%	4.1	41.4	9%
50	24	41.7	10.4	31.3	25%	4.4	37.3	11%
50	26	38.5	11.2	27.3	29%	6.4	32.1	17%
50	28	35.7	13.3	22.4	37%	6.6	29.1	18%
50	30	33.3	14.7	18.6	44%	6.3	27.0	19%
50	32	31.3	15.0	16.3	48%	5.9	25.4	19%
50	34	29.4	11.1	18.3	38%	5.1	24.3	17%
50	36	27.8	13.7	14.1	49%	4.8	23.0	17%
50	38	26.3	15.7	10.6	60%	7.4	18.9	28%
50	40	25.0	15.8	9.2	63%	9.2	15.8	37%
50	42	23.8	13.9	9.9	58%	8.8	15.0	37%
50	44	22.7	15.1	7.6	66%	8.8	13.9	39%
50	46	21.7	16.9	4.8	78%	10.8	10.9	50%
50	48	20.8	N/A	N/A	N/A	14.1	6.7	68%
50	50	20.0	N/A	N/A	N/A	17.0	3.0	85%
100	1	1000.0	10.6	989.4	1%	4.8	995.2	0%
100	2	500.0	9.4	490.6	2%	4.4	495.6	1%
100	4	250.0	9.6	240.4	4%	4.8	245.2	2%
100	10	100.0	15.6	84.4	16%	5.8	94.2	6%
100	12	83.3	14.6	68.7	18%	6.6	76.7	8%
100	14	71.4	17.2	54.2	24%	7.6	63.8	11%
100	16	62.5	16.4	46.1	26%	6.4	56.1	10%
100	18	55.6	18.0	37.6	32%	6.2	49.4	11%
100	20	50.0	18.2	31.8	36%	7.6	42.4	15%
100	22	45.5	17.8	27.7	39%	8.2	37.3	18%
100	24	41.7	16.4	25.3	39%	7.6	34.1	18%
100	26	38.5	22.4	16.1	58%	8.2	30.3	21%
100	28	35.7	33.8	1.9	95%	8.2	27.5	23%
100	30	33.3	N/A	N/A	N/A	9.0	24.3	27%
100	32	31.3	N/A	N/A	N/A	9.2	22.1	29%
100	34	29.4	N/A	N/A	N/A	9.6	19.8	33%
100	36	27.8	N/A	N/A	N/A	9.6	18.2	35%
100	38	26.3	N/A	N/A	N/A	10.6	15.7	40%
100	40	25.0	N/A	N/A	N/A	11.4	13.6	46%
100	42	23.8	N/A	N/A	N/A	16.0	7.8	67%
100	44	22.7	N/A	N/A	N/A	15.4	7.3	68%
100	46	21.7	N/A	N/A	N/A	15.6	6.1	72%

Table 1. THVD1450 Jitter Test Results (continued)

Cable Length (m)	Data Rate (Mbps)	Bit Duration (ns)	Differential Jitter (ns)	Eye Width (ns)	Total Differential Jitter	Output Jitter (ns)	Eye Width (ns)	Total Output Jitter[1]
100	48	20.8	N/A	N/A	N/A	N/A	N/A	N/A
100	50	20.0	N/A	N/A	N/A	N/A	N/A	N/A
150	1	1000.0	23.6	976.4	2%	14.8	985.2	1%
150	2	500.0	21.2	478.8	4%	12.0	488.0	2%
150	4	250.0	20.4	229.6	8%	10.4	239.6	4%
150	6	166.7	22.0	144.7	13%	14.0	152.7	8%
150	8	125.0	24.0	101.0	19%	12.0	113.0	10%
150	10	100.0	30.8	69.2	31%	14.4	85.6	14%
150	12	83.3	26.8	56.5	32%	15.2	68.1	18%
150	14	71.4	25.6	45.8	36%	12.0	59.4	17%
150	16	62.5	31.6	30.9	51%	14.4	48.1	23%
150	18	55.6	31.2	24.4	56%	17.2	38.4	31%
150	20	50.0	28.0	22.0	56%	18.4	31.6	37%
150	22	45.5	36.4	9.1	80%	16.7	28.8	37%
150	24	41.7	39.0	2.7	94%	18.4	23.3	44%
150	26	38.5	N/A	N/A	N/A	20.8	17.7	54%
150	28	35.7	N/A	N/A	N/A	22.8	12.9	64%
150	30	33.3	N/A	N/A	N/A	24.8	8.5	74%
200	1	1000.0	27.6	972.4	3%	11.6	988.4	1%
200	2	500.0	30.0	470.0	6%	12.0	488.0	2%
200	4	250.0	27.6	222.4	11%	14.4	235.6	6%
200	6	166.7	28.8	137.9	17%	14.4	152.3	9%
200	8	125.0	31.2	93.8	25%	19.2	105.8	15%
200	10	100.0	40.8	59.2	41%	20.0	80.0	20%
200	12	83.3	34.4	48.9	41%	19.2	64.1	23%
200	14	71.4	28.0	43.4	39%	20.0	51.4	28%
200	16	62.5	34.4	28.1	55%	23.2	39.3	37%
200	18	55.6	42.8	12.8	77%	21.2	34.4	38%
200	20	50.0	N/A	N/A	N/A	24.8	25.2	50%
1000	0.1	10000.0	1088.0	8912.0	11%	704.0	9296.0	7%
1000	0.2	5000.0	1136.0	3864.0	23%	696.0	4304.0	14%
1000	0.4	2500.0	912.0	1588.0	36%	688.0	1812.0	28%
1000	0.6	1666.7	944.0	722.7	57%	600.0	1066.7	36%
1000	0.8	1250.0	936.0	314.0	75%	648.0	602.0	52%
1000	1	1000.0	840.0	160.0	84%	712.0	288.0	71%

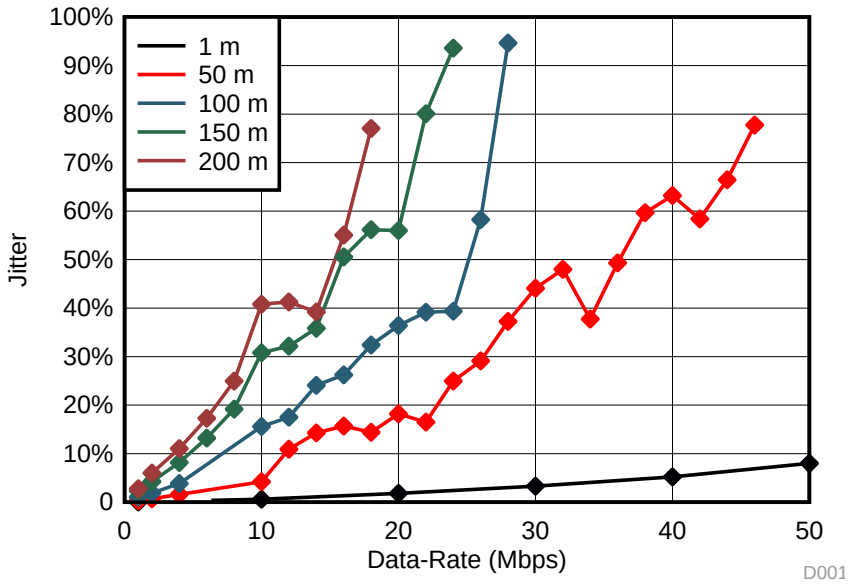

Figure 2. THVD1450 Differential Jitter

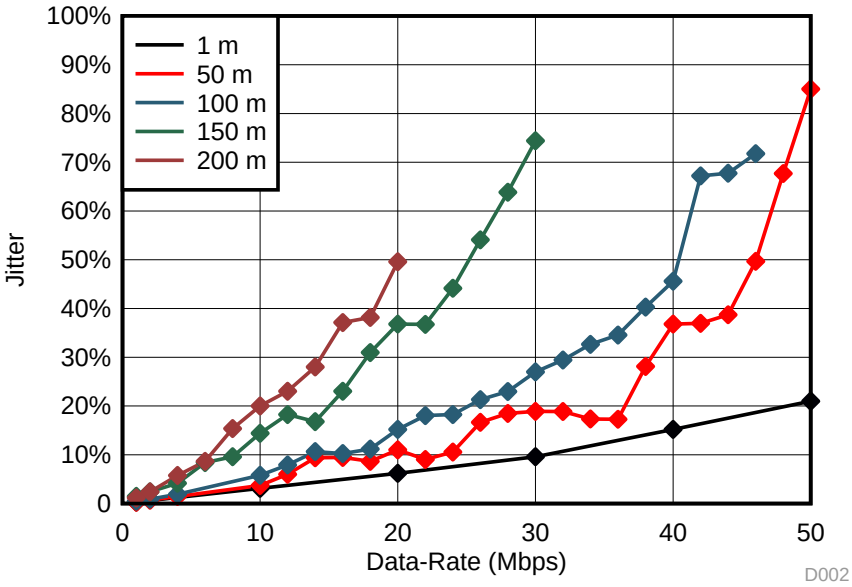

Figure 3. THVD1450 Output Jitter

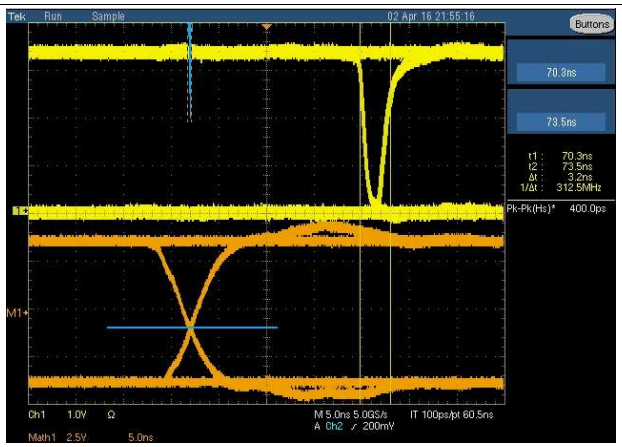

Figure 4. 1 Meter at 1 Mbps

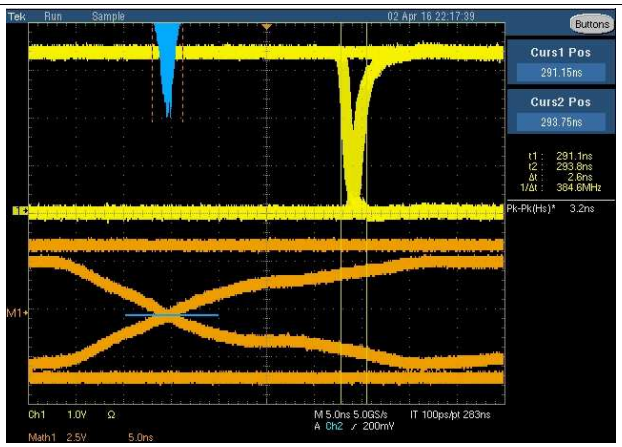

Figure 5. 50 Meters at 1 Mbps

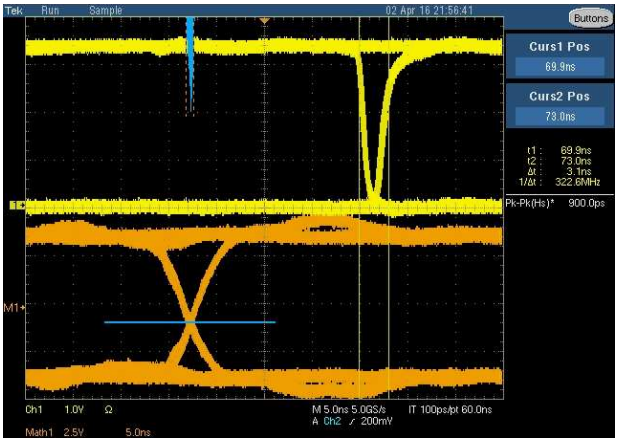

Figure 6. 1 Meter at 20 Mbps

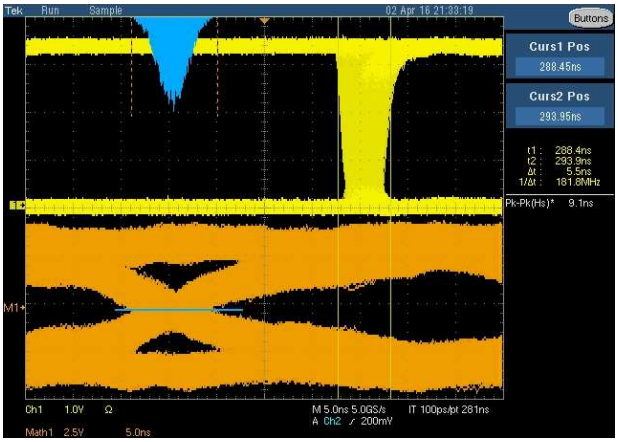

Figure 7. 50 Meters at 20 Mbps

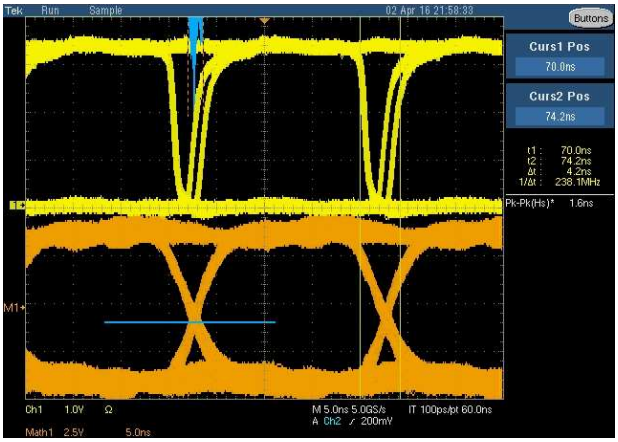

Figure 8. 1 Meter at 50 Mbps

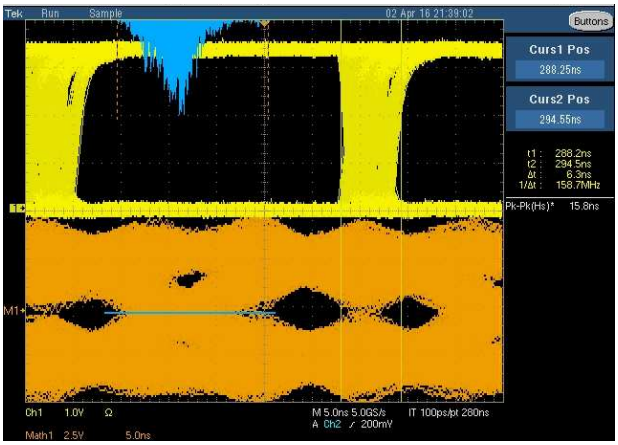

Figure 9. 50 Meters at 30 Mbps

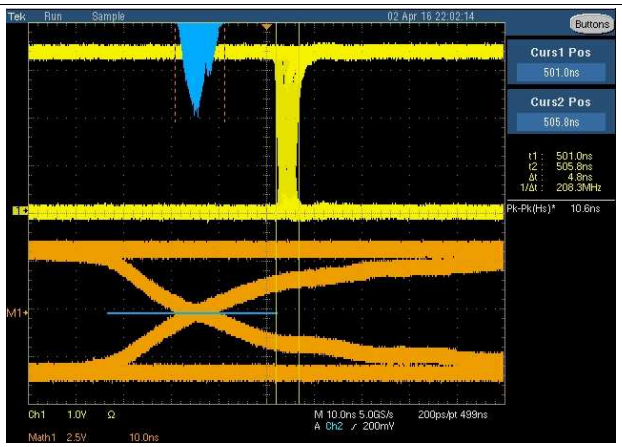

Figure 10. 100 Meters at 1 Mbps

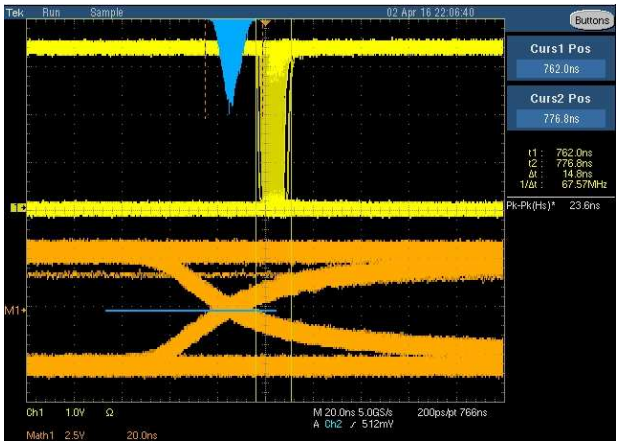

Figure 11. 150 Meters at 1 Mbps

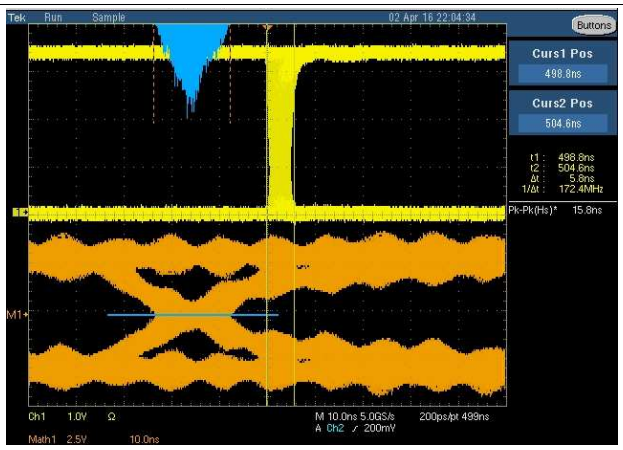

Figure 12. 100 Meters at 10 Mbps

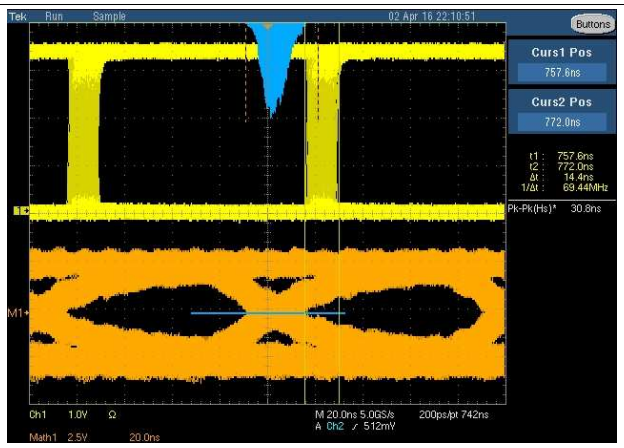

Figure 13. 150 Meters at 10 Mbps

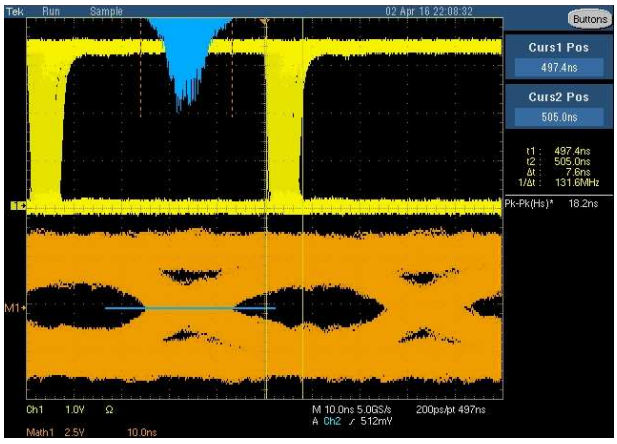

Figure 14. 100 Meters at 20 Mbps

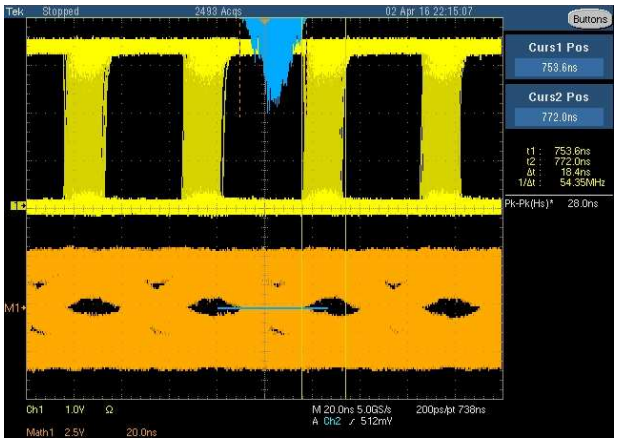

Figure 15. 150 Meters at 20 Mbps

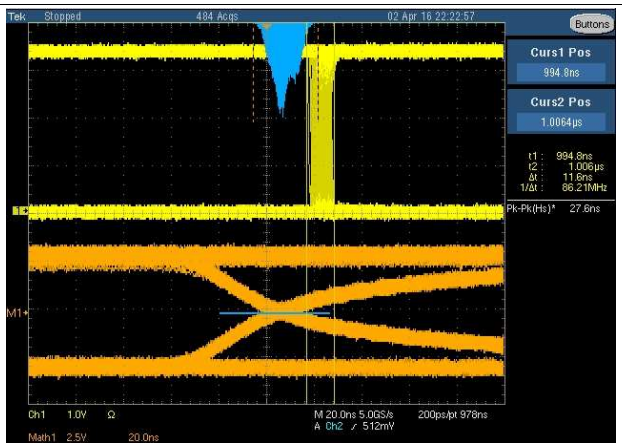

Figure 16. 200 Meters at 1 Mbps

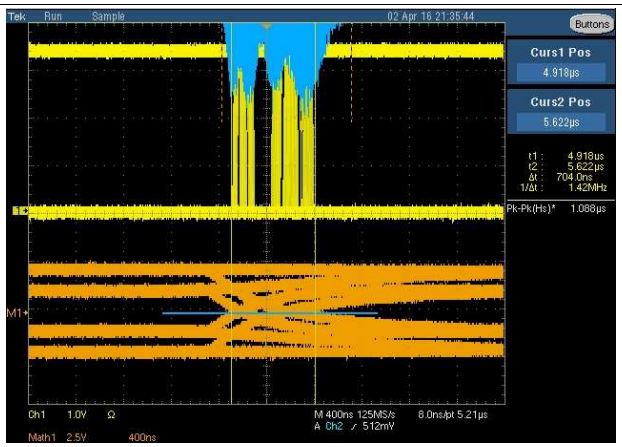

Figure 17. 1000 Meters at 1 Mbps

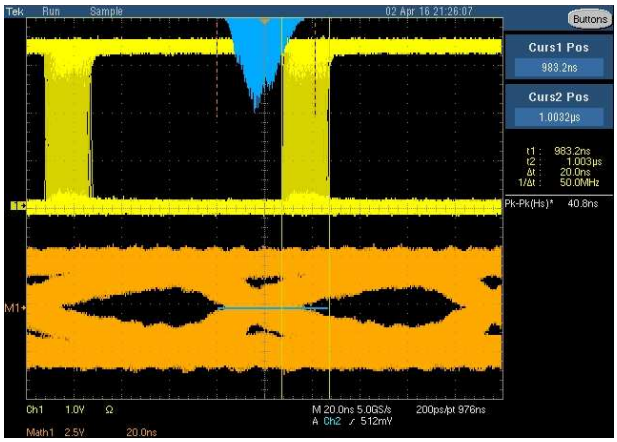

Figure 18. 200 Meters at 10 Mbps

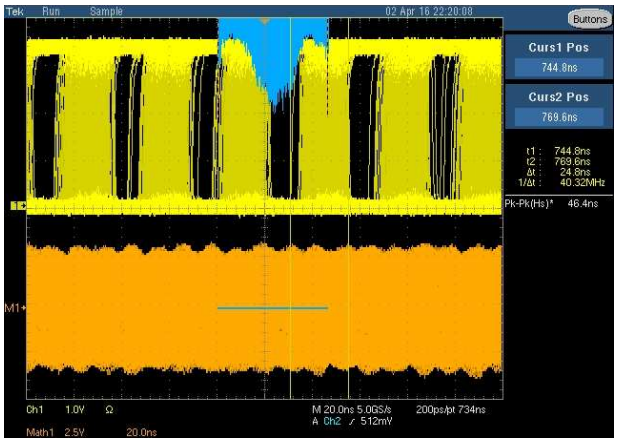

Figure 19. 200 Meters at 20 Mbps

Table 2. THVD1429 Jitter Test Results

Cable Length (m)	Data Rate (Mbps)	Bit Duration (ns)	Differential Jitter (ns)	Eye Width (ns)	Total Differential Jitter	Output Jitter (ns)	Eye Width (ns)	Total Output Jitter[(1)]
1	1	1000.0	2.6	997.4	0%	3.2	996.8	0%
1	2	500.0	2.4	497.6	0%	2.8	497.2	1%
1	4	250.0	2.4	247.6	1%	3.0	247.0	1%
1	6	166.7	2.4	164.3	1%	3.2	163.5	2%
1	8	125.0	2.4	122.6	2%	3.4	121.6	3%
1	10	100.0	2.8	97.2	3%	3.4	96.6	3%
1	12	83.3	2.8	80.5	3%	3.8	79.5	5%
1	14	71.4	3.0	68.4	4%	4.8	66.6	7%
1	16	62.5	3.4	59.1	5%	4.8	57.7	8%
1	18	55.6	4.0	51.6	7%	5.4	50.2	10%
1	20	50.0	4.2	45.8	8%	5.4	44.6	11%
50	1	1000.0	10.2	989.8	1%	5.4	994.6	1%
50	2	500.0	11.0	489.0	2%	7.4	492.6	1%
50	4	250.0	17.2	232.8	7%	14.6	235.4	6%
50	6	166.7	17.6	149.1	11%	13.4	153.3	8%

(1) The level of acceptable jitter in a given application would be dependent on the overall serial communications system implementation. Most systems can tolerate around 20% without a substantial increase in bit error rate, and some may tolerate jitter levels as high as 50%.

Table 2. THVD1429 Jitter Test Results (continued)

Cable Length (m)	Data Rate (Mbps)	Bit Duration (ns)	Differential Jitter (ns)	Eye Width (ns)	Total Differential Jitter	Output Jitter (ns)	Eye Width (ns)	Total Output Jitter[1]
50	8	125.0	16.4	108.6	13%	13.4	111.6	11%
50	10	100.0	18.4	81.6	18%	15.6	84.4	16%
50	12	83.3	21.2	62.1	25%	21.0	62.3	25%
50	14	71.4	24.0	47.4	34%	22.0	49.4	31%
50	16	62.5	24.8	37.7	40%	23.8	38.7	38%
50	18	55.6	24.4	31.2	44%	22.0	33.6	40%
50	20	50.0	28.8	21.2	58%	20.8	29.2	42%
100	1	1000.0	10.8	989.2	1%	6.4	993.6	1%
100	2	500.0	14.6	485.4	3%	9.6	490.4	2%
100	4	250.0	14.0	236.0	6%	9.8	240.2	4%
100	6	166.7	18.4	148.3	11%	14.0	152.7	8%
100	8	125.0	15.0	110.0	12%	10.8	114.2	9%
100	10	100.0	21.0	79.0	21%	15.4	84.6	15%
100	12	83.3	22.2	61.1	27%	18.2	65.1	22%
100	14	71.4	22.8	48.6	32%	11.8	59.6	17%
100	16	62.5	23.6	38.9	38%	15.0	47.5	24%
100	18	55.6	22.6	33.0	41%	15.8	39.8	28%
100	20	50.0	28.2	21.8	56%	17.6	32.4	35%
150	1	1000.0	19.0	981.0	2%	8.6	991.4	1%
150	2	500.0	18.4	481.6	4%	10.2	489.8	2%
150	4	250.0	20.0	230.0	8%	11.2	238.8	4%
150	6	166.7	27.2	139.5	16%	18.2	148.5	11%
150	8	125.0	19.8	105.2	16%	14.0	111.0	11%
150	10	100.0	29.8	70.2	30%	19.0	81.0	19%
150	12	83.3	34.0	49.3	41%	21.8	61.5	26%
150	14	71.4	23.4	48.0	33%	16.0	55.4	22%
150	16	62.5	35.2	27.3	56%	24.8	37.7	40%
150	18	55.6	33.8	21.8	61%	25.4	30.2	46%
150	20	50.0	40.6	9.4	81%	27.8	22.2	56%
200	1	1000.0	29.2	970.8	3%	12.2	987.8	1%
200	2	500.0	28.4	471.6	6%	15.6	484.4	3%
200	4	250.0	31.0	219.0	12%	20.0	230.0	8%
200	6	166.7	33.4	133.3	20%	21.8	144.9	13%
200	8	125.0	29.4	95.6	24%	23.0	102.0	18%
200	10	100.0	40.8	59.2	41%	29.8	70.2	30%
200	12	83.3	38.4	44.9	46%	30.8	52.5	37%
200	14	71.4	33.6	37.8	47%	33.6	37.8	47%
200	16	62.5	40.6	21.9	65%	30.0	32.5	48%
200	18	55.6	N/A	N/A	N/A	37.2	18.4	67%
200	20	50.0	N/A	N/A	N/A	39.4	10.6	79%

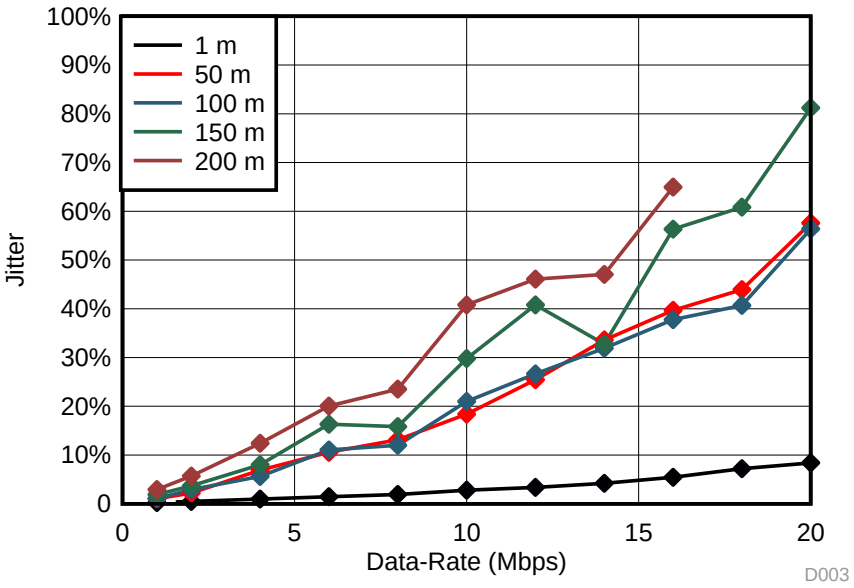

Figure 20. THVD1429 Differential Jitter

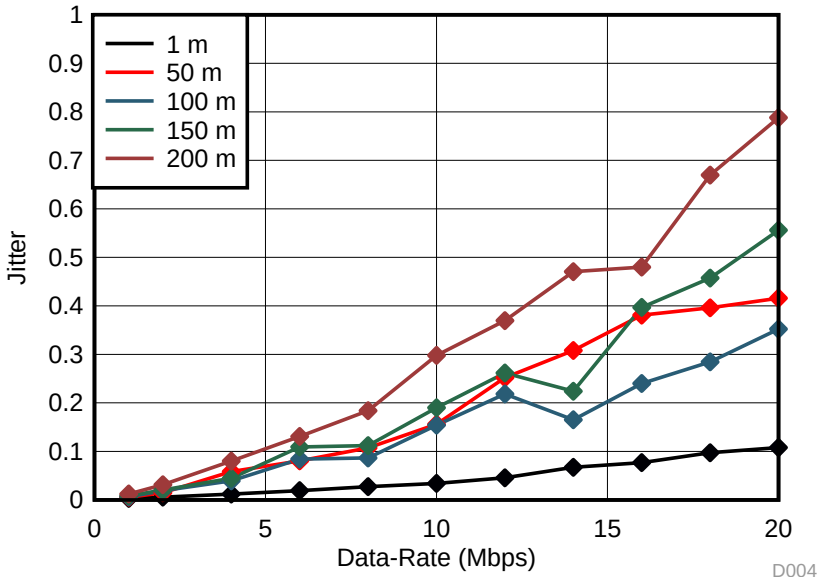

Figure 21. THVD1429 Output Jitter

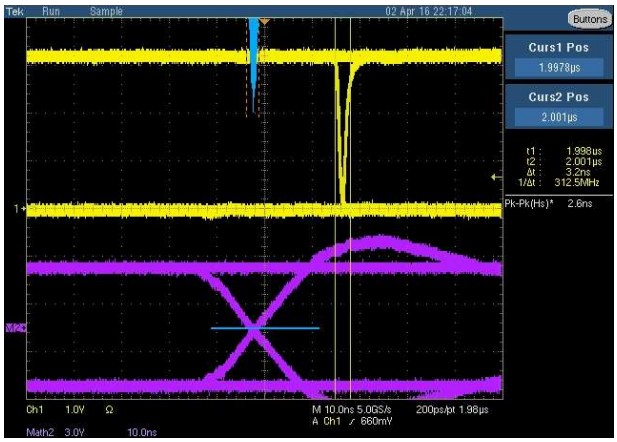

Figure 22. 1 Meters at 1 Mbps

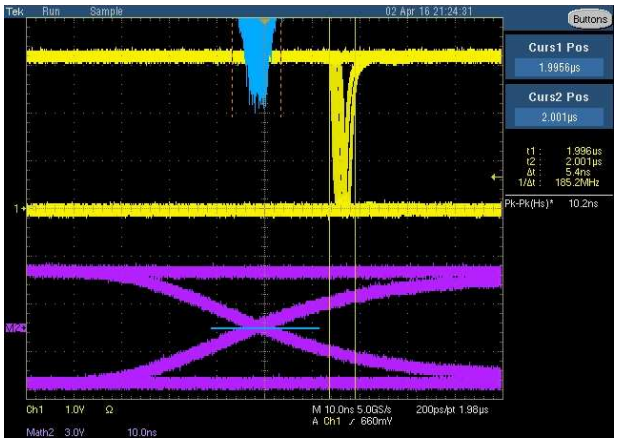

Figure 23. 50 Meters at 1 Mbps

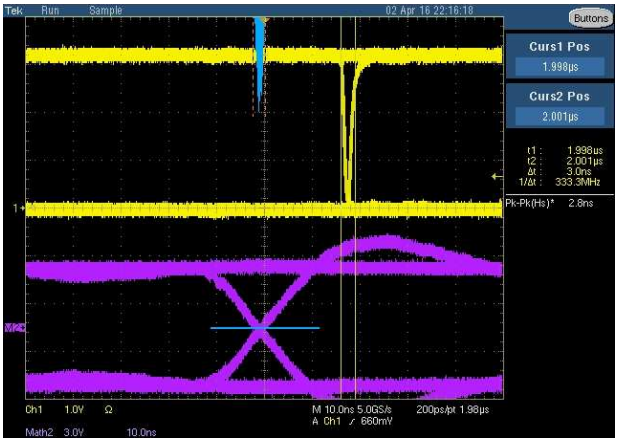

Figure 24. 1 Meters at 10 Mbps

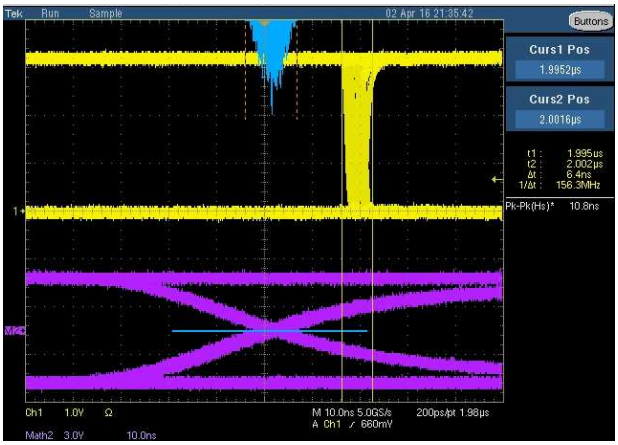

Figure 25. 50 Meters at 10 Mbps

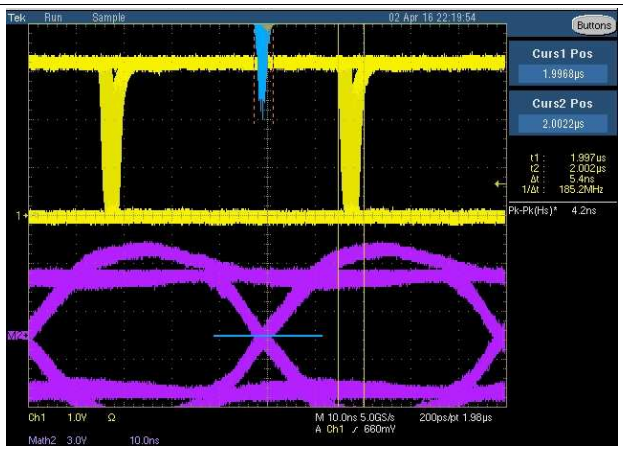

Figure 26. 1 Meters at 20 Mbps

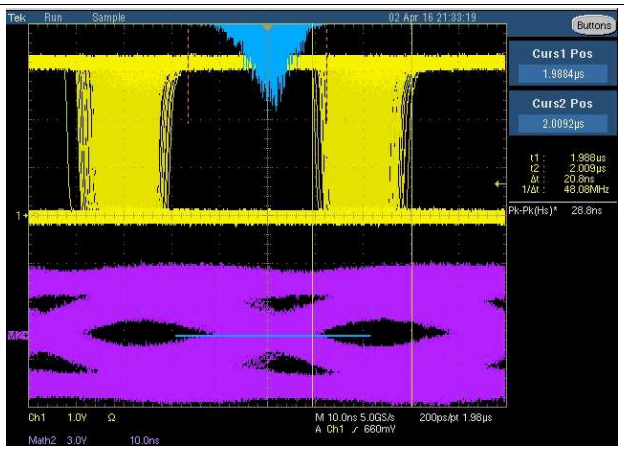

Figure 27. 50 Meters at 20 Mbps

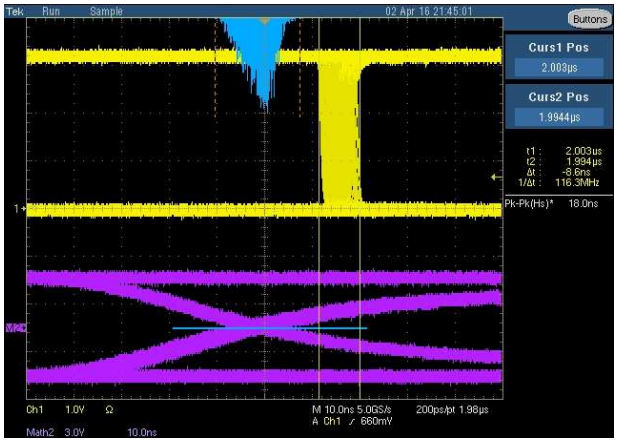

Figure 28. 100 Meters at 1 Mbps

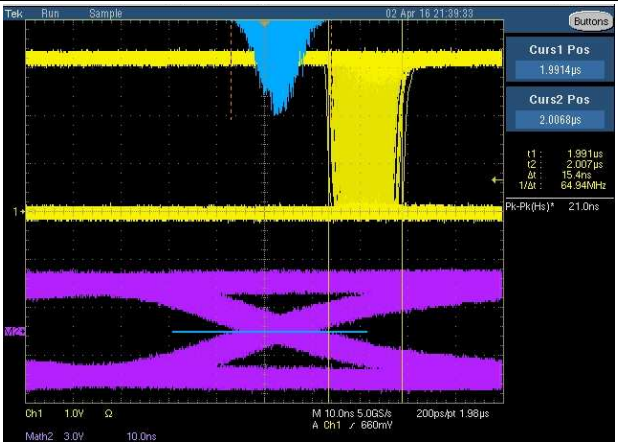

Figure 29. 150 Meters at 1 Mbps

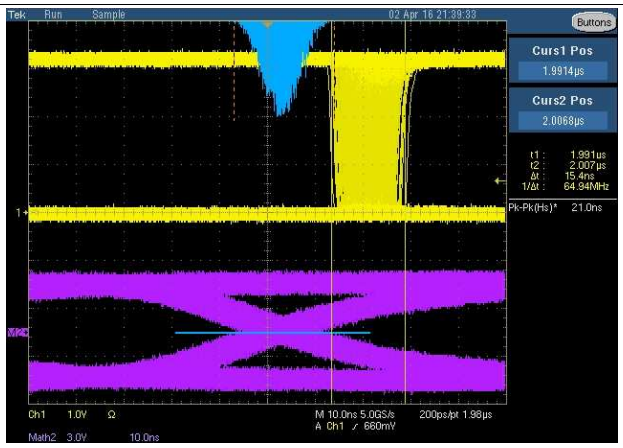

Figure 30. 100 Meters at 10 Mbps

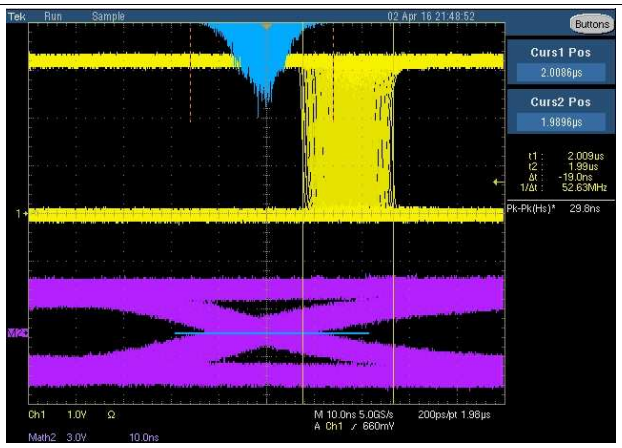

Figure 31. 150 Meters at 10 Mbps

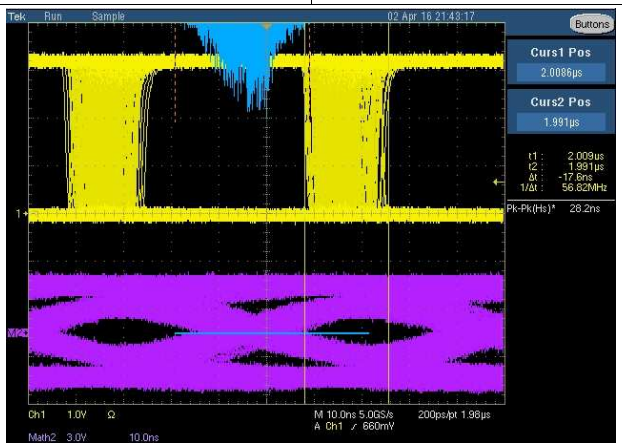

Figure 32. 100 Meters at 20 Mbps

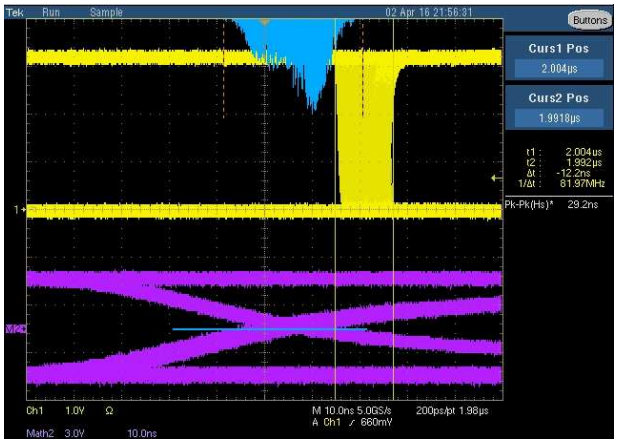

Figure 33. 200 Meters at 1 Mbps

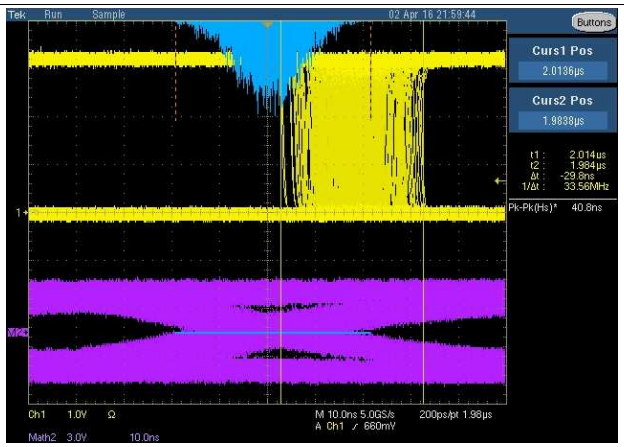

Figure 34. 200 Meters at 10 Mbps

5 Summary

The correlation between cable length and jitter can be clearly seen from these measurements. The specific points at which certain jitter thresholds are reached depend on many elements of the system being implemented and may vary from the results of this test, but the trend indicated by these readings may serve as a guide for reference.

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