PERFORMANCE AND SCALABILITY *OF* NETWORKS SYSTEMS *WITH* (EMBEDDED) BOUNDARY CLOCKS

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November 1st to 3rd , ITSF 2011- Edinburg

Introduction   Cont

The Time aware/ capable networks are gaining acceptance in Telecom networks and other fields.

To meet the level of precision of frequency and phase delivery,

These networks would include

- Boundary clocks
- Transparent clocks

In this presentation we

- Look at selected network topologies
- Corresponding performance data
    - Frequency
    - Phase

Agenda

- Brief look at test topologies
- Discussion of selected test results
- Highlights of results
- Suggestions for possible deployment

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Test Network Topologies

Use Modified G.8262 Appendix VI topologies

Boundary Clock Implementations

- Implementation A- Both slave and Master on the same line card
- Implementation B - Slave and Master on different line cards

The test data set is small……

Fine print

Following slides depict the network test topologies

constructed given the perpetual constrains

- Time
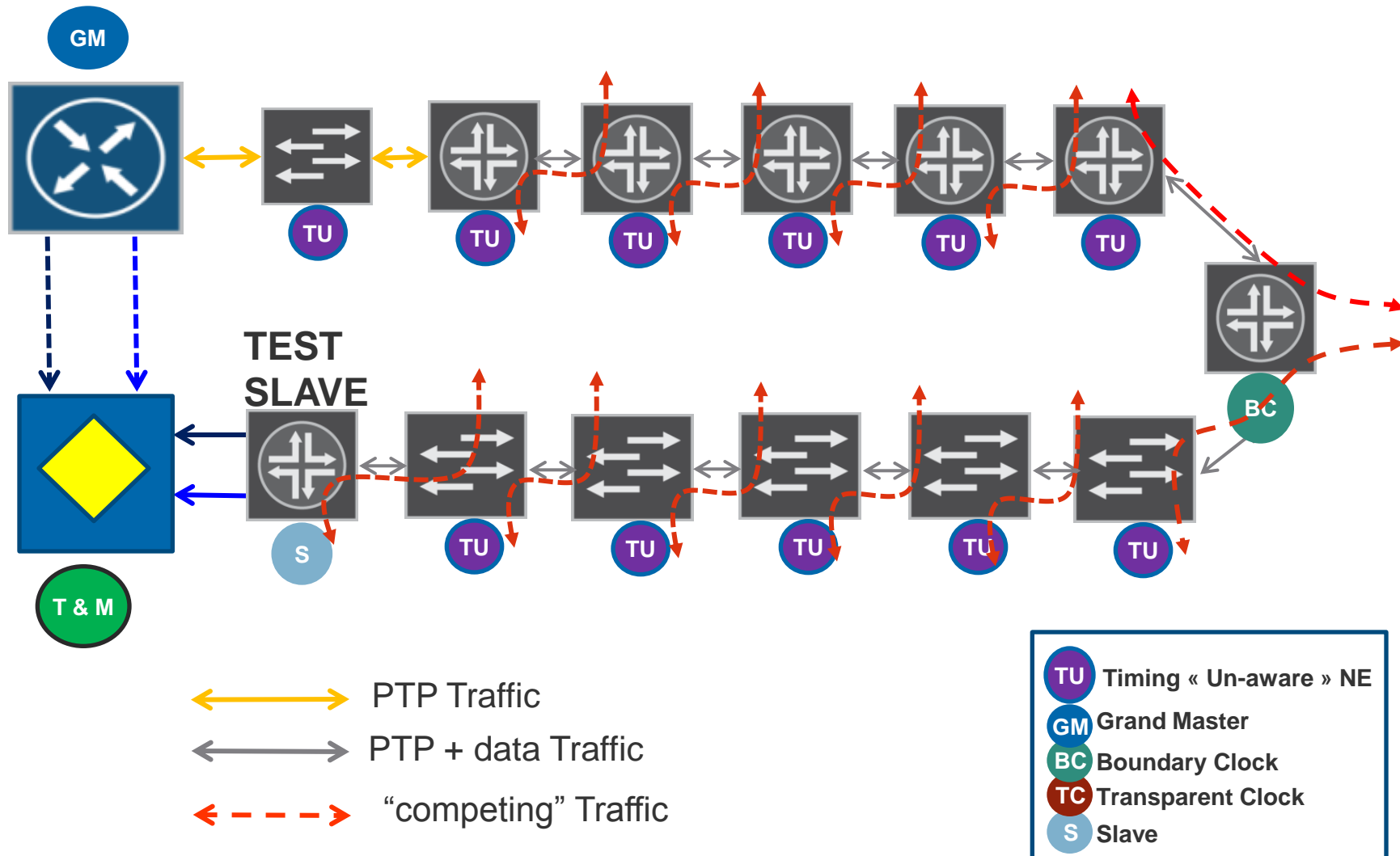- Man power
- Equipment availability

So the tests topologies may not be as exhaustive ………

…………………..as i would have liked them to be
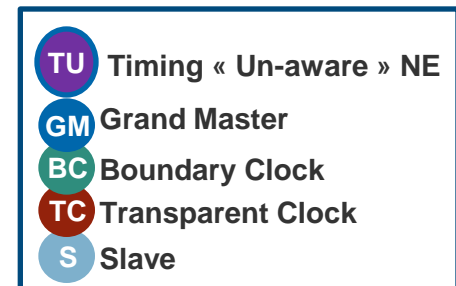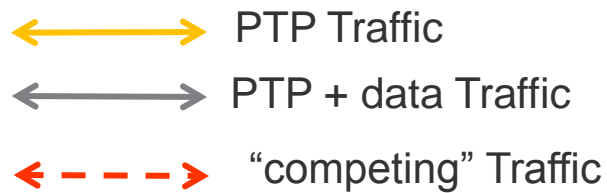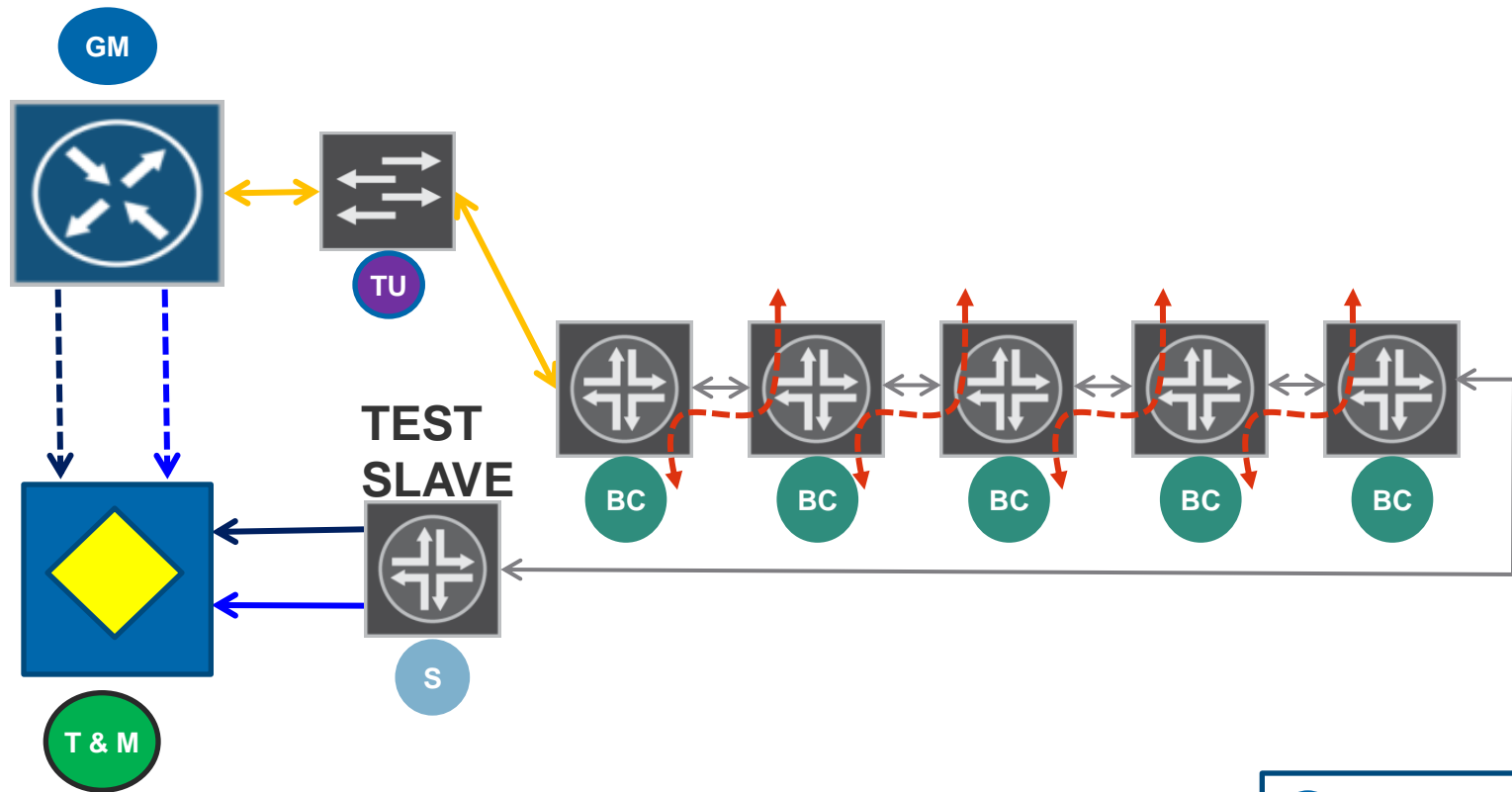
The test results are indicative and not conclusive

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TEST TOPOLOGY -I
10 N/W HOPS OF TIMING UNAWARE ROUTERS

GM

TU

TU

TU

TU

TU

TU

TEST SLAVE

S

TU

TU

TU

TU

TU

T & M

PTP Traffic

PTP + data Traffic

"competing" Traffic

TU	Timing « Un-aware » NE
GM	Grand Master
BC	Boundary Clock
TC	Transparent Clock
S	Slave

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TEST TOPOLOGY -II

12 N/W HOPS WITH 1 BC IN THE MIDDLE

GM

TEST SLAVE

T & M

PTP Traffic

PTP + data Traffic

"competing" Traffic

TU	Timing « Un-aware » NE
GM	Grand Master
BC	Boundary Clock
TC	Transparent Clock
S	Slave

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TEST TOPOLOGY -III

6 N/W HOPS WITH 5 BOUNDARY CLOCKS

GM

TU

TEST SLAVE

BC **BC** **BC** **BC** **BC**

S

T & M

PTP Traffic

PTP + data Traffic

"competing" Traffic

TU Timing « Un-aware » NE
GM Grand Master
BC Boundary Clock
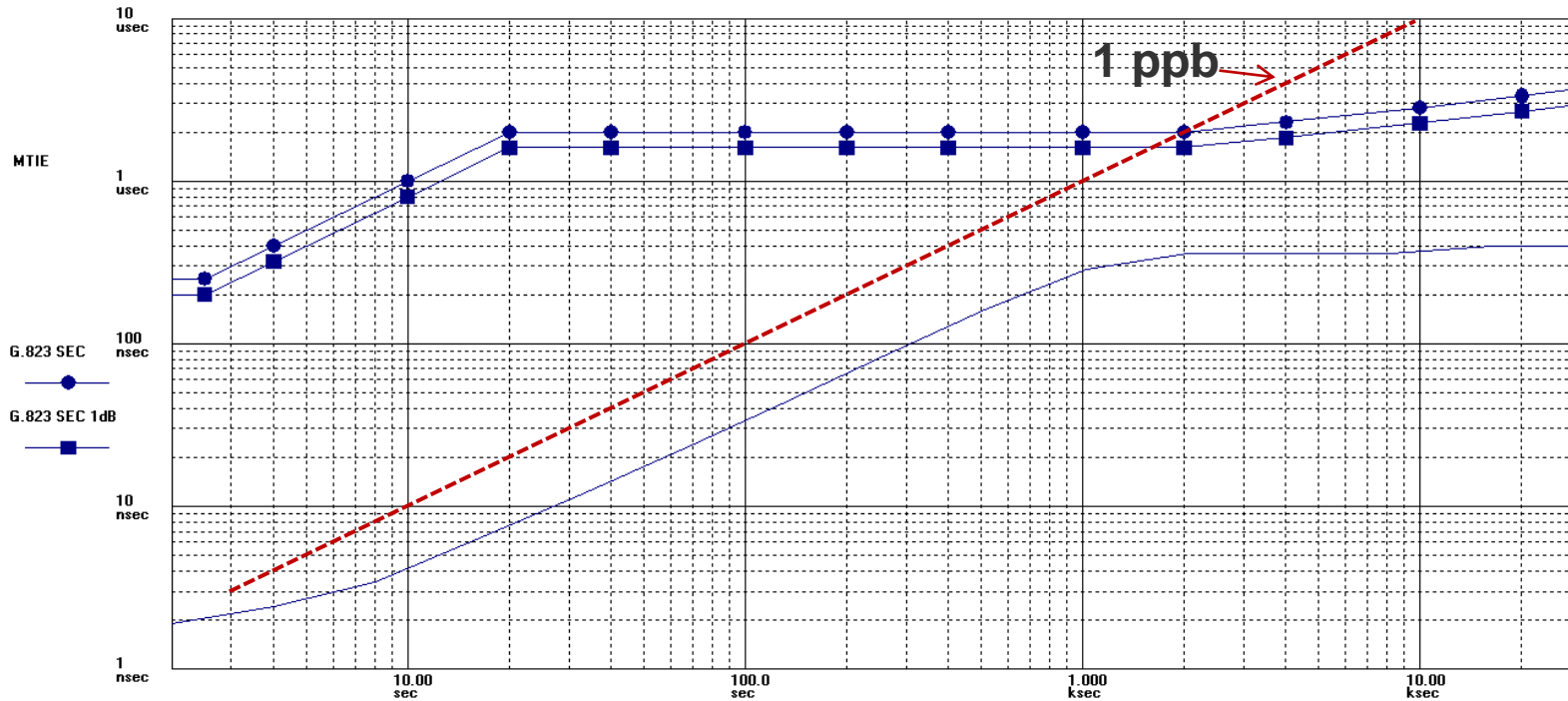**TC** Transparent Clock
S Slave

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Overview of the Test results

TEST CASE 13 TM1

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.0 mHz; *10/3/2011 1:11:37 AM*; *10/3/2011 9:24:03 AM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 14742; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
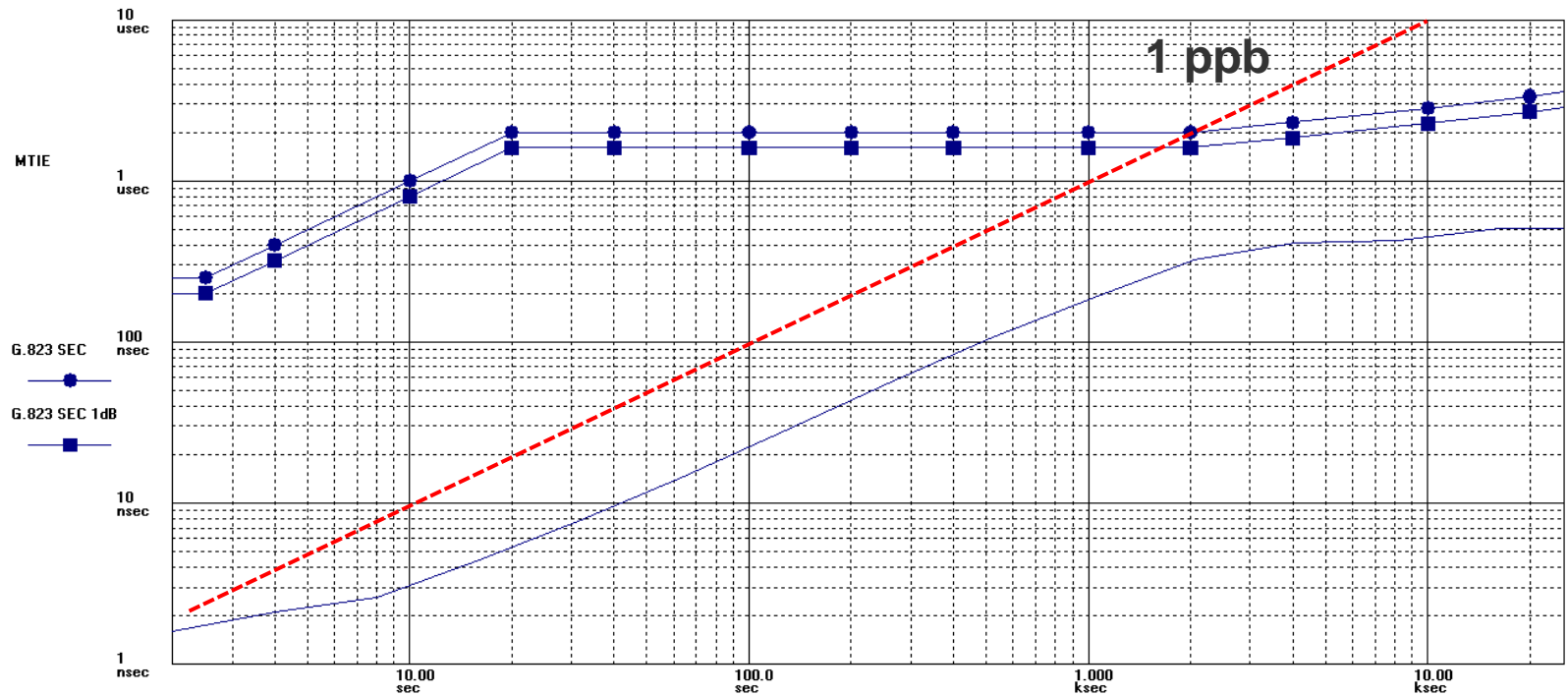TAZ-10mh

FFO -0.8 to +0.95 ppb

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12 HOPS 1 BC (IMPL. A)

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.9 mHz; *7/26/2011 10:30:28 PM*; *7/27/2011 8:54:16 AM*;
HP 53132A; Test: 1;   TAZ-TIE;   Samples: 12600;   Gate: 1 s;   Stop: 12600;   Total Points: 18711;   Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
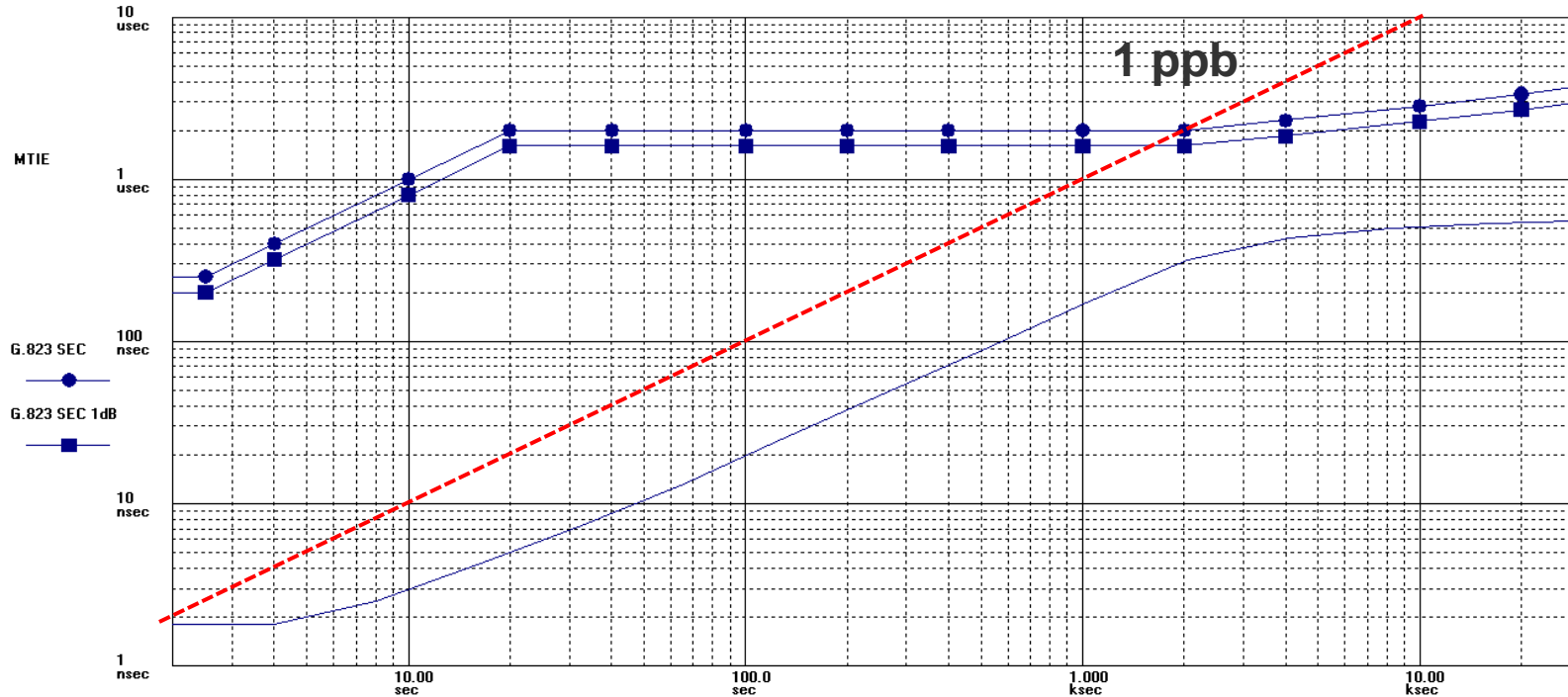TAZ-10mh

1 ppb

MTIE

G.823 SEC

G.823 SEC 1dB

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TEST CASE 13 TM1

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=500.0 mHz; *7/17/2011 10:55:47 PM*; *7/18/2011 8:54:49 AM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 14400; Gate: 1 s; Stop: 14400; Total Points: 17970; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
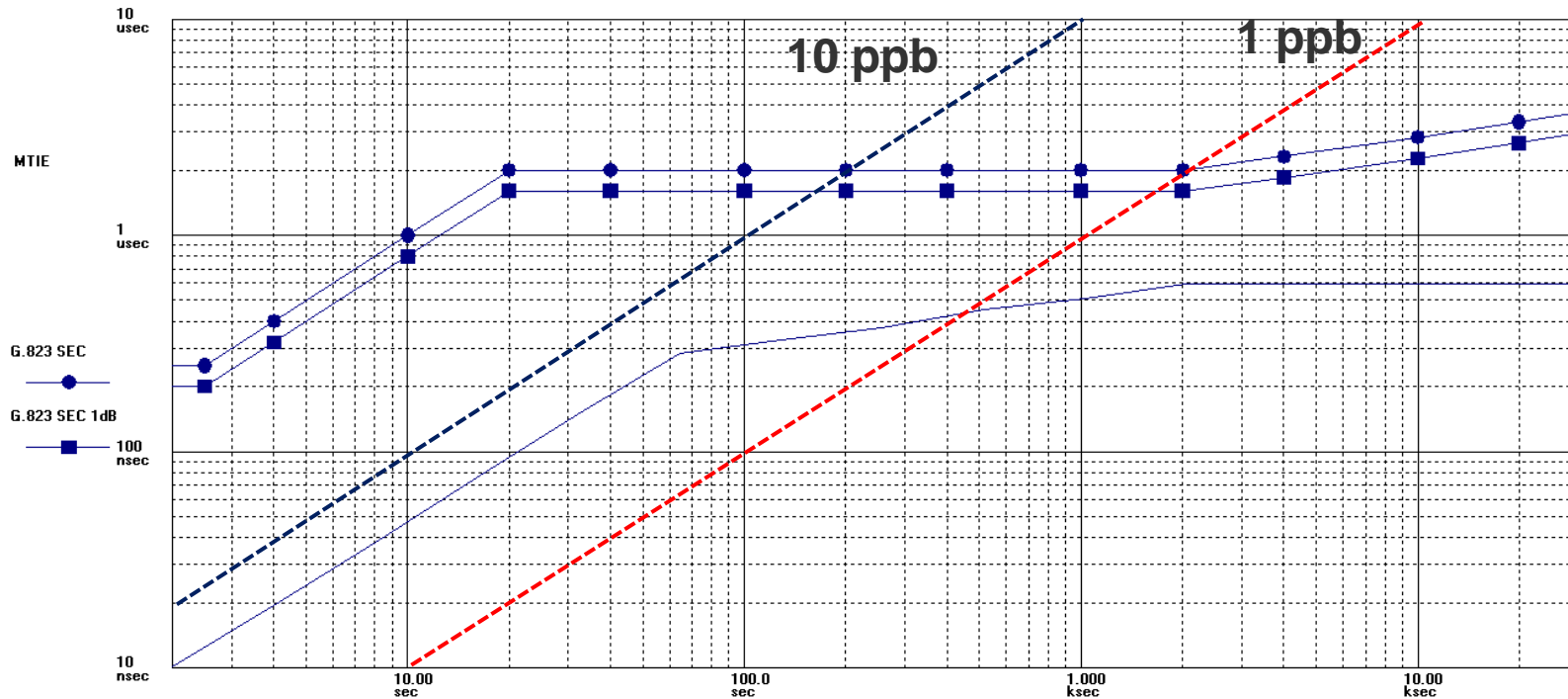TAZ-10mh

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TEST CASE 13 TM1

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.0 mHz; *8/8/2011 10:27:43 PM*; *8/9/2011 9:09:47 AM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 14400; Gate: 1 s; Stop: 14400; Total Points: 19232; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
TAZ-10mh

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SUMMARY TC13 TM1

FFO (LSF)

Symmetricom TimeMonitor Analyzer   (file=5BC_taz_10mh_00001.dat)
Least square fit fractional frequency offset vs. time; N=100; 2011/09/19; 21:54:51
0 (black): HP 53132A; Test: 1; TAZ-TIE; Samples: 20528; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/09/19; 21:54:51
1 (blue): HP 53132A; Test: 1; TAZ-TIE; Samples: 17970; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/07/17; 22:55:48
2 (red): HP 53132A; Test: 1; TAZ-TIE; Samples: 18711; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/07/26; 22:30:29
3 (magenta): HP 53132A; Test: 1; TAZ-TIE; Samples: 19232; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/08/08; 22:27:45
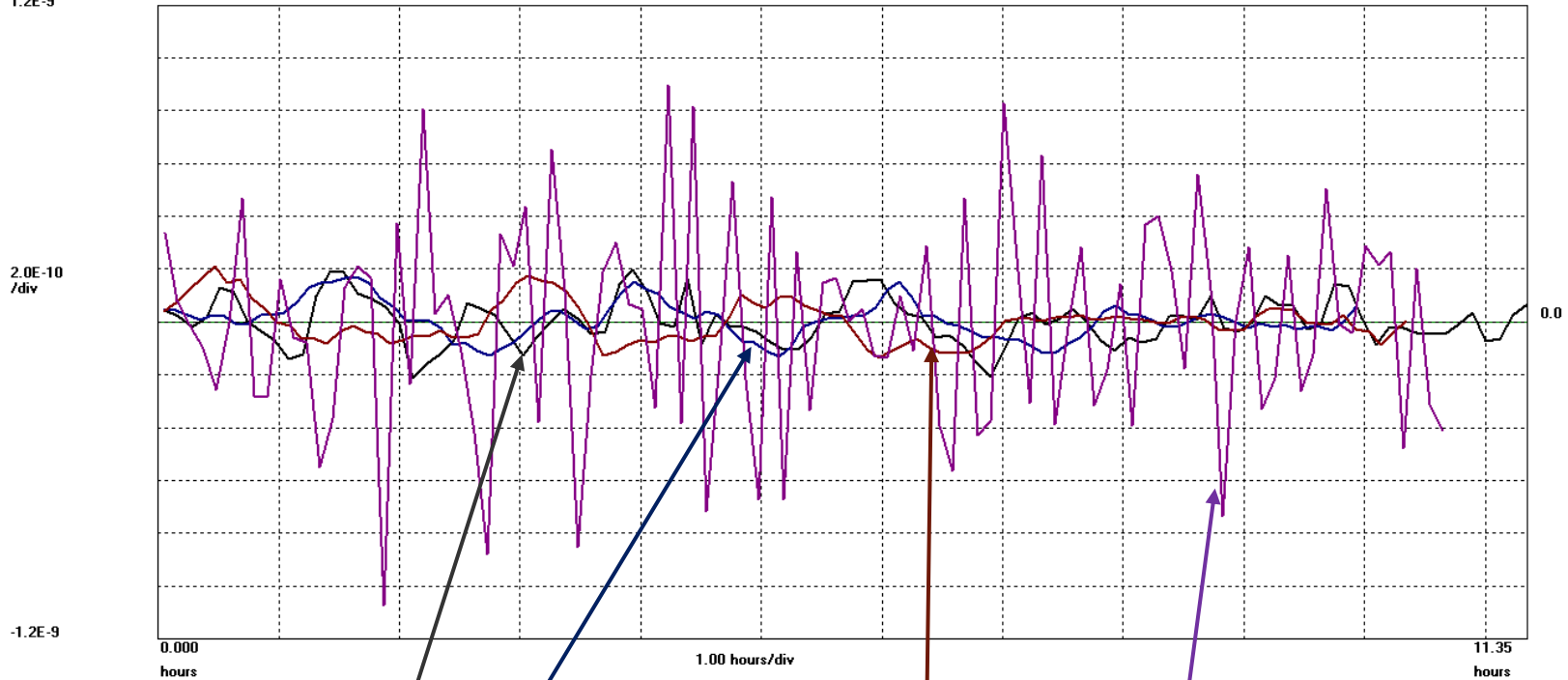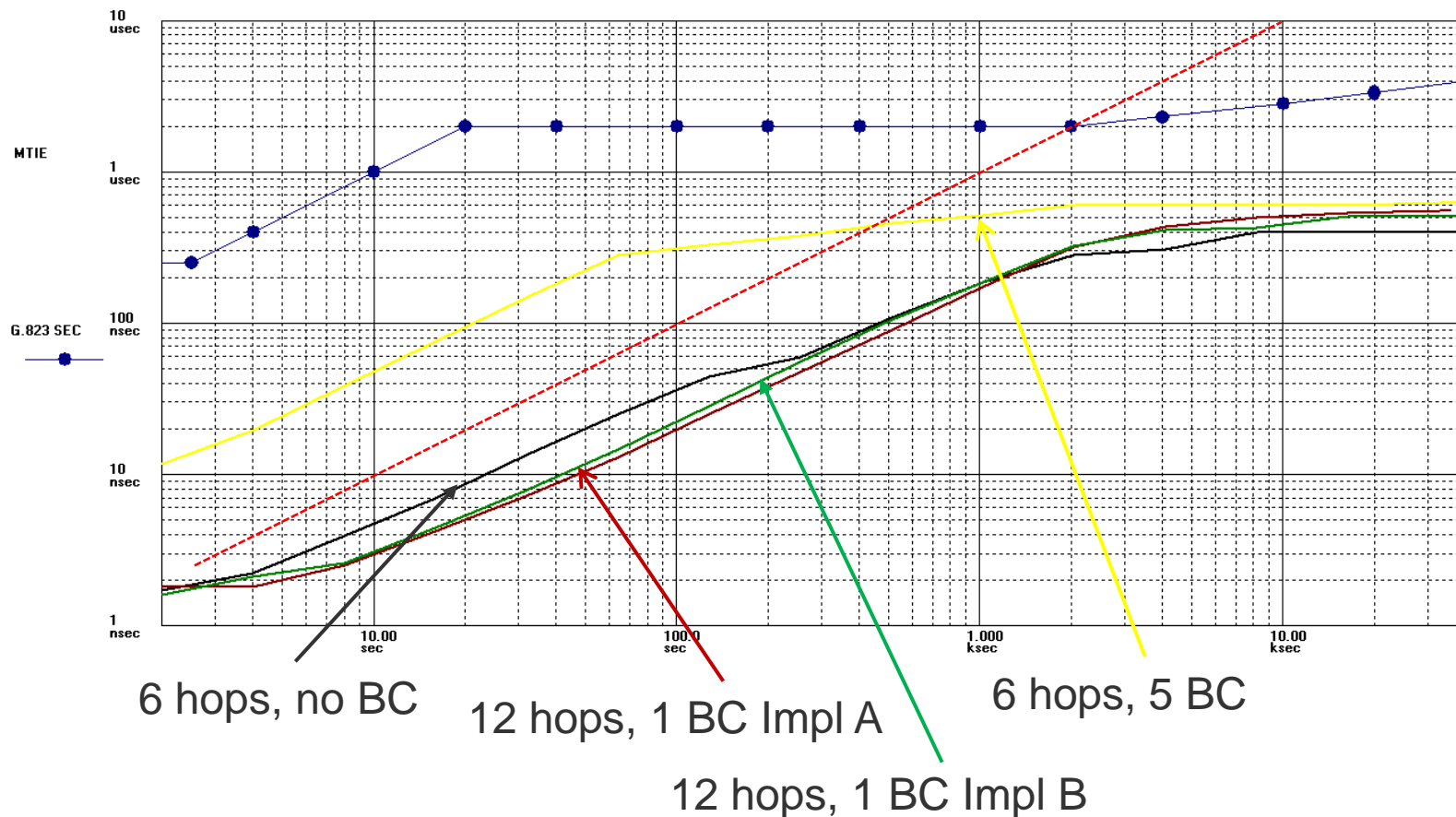
6 hops, no BC

12 hops, 1 BC Impl A
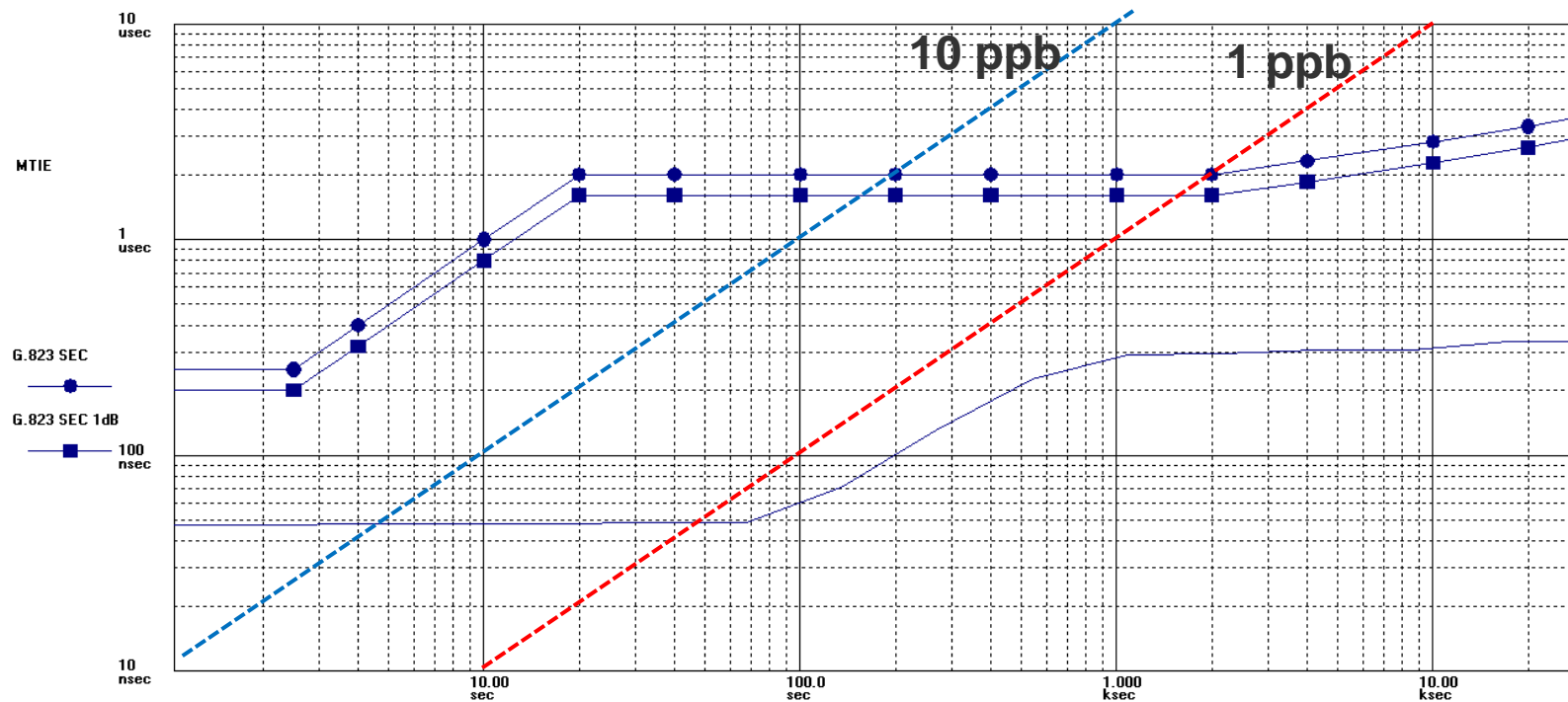
12 hops, 1 BC Impl B

6 hops, 5 BC

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MTIE

Symmetricom TimeMonitor Analyzer   (file=5BC_taz_10mh_00001.dat)
MTIE; Fo=10.00 MHz; Fs=500.0 mHz; 2011/09/19; 21:54:51

6 hops, no BC

12 hops, 1 BC Impl A

12 hops, 1 BC Impl B

6 hops, 5 BC

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Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=951.3 mHz; *7/5/2011 4:10:18 PM*; *7/5/2011 11:57:45 PM*;
HP 53132A; Test: 1;   TAZ-TIE;   Samples: 26681;   Gate: 1 s;   Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
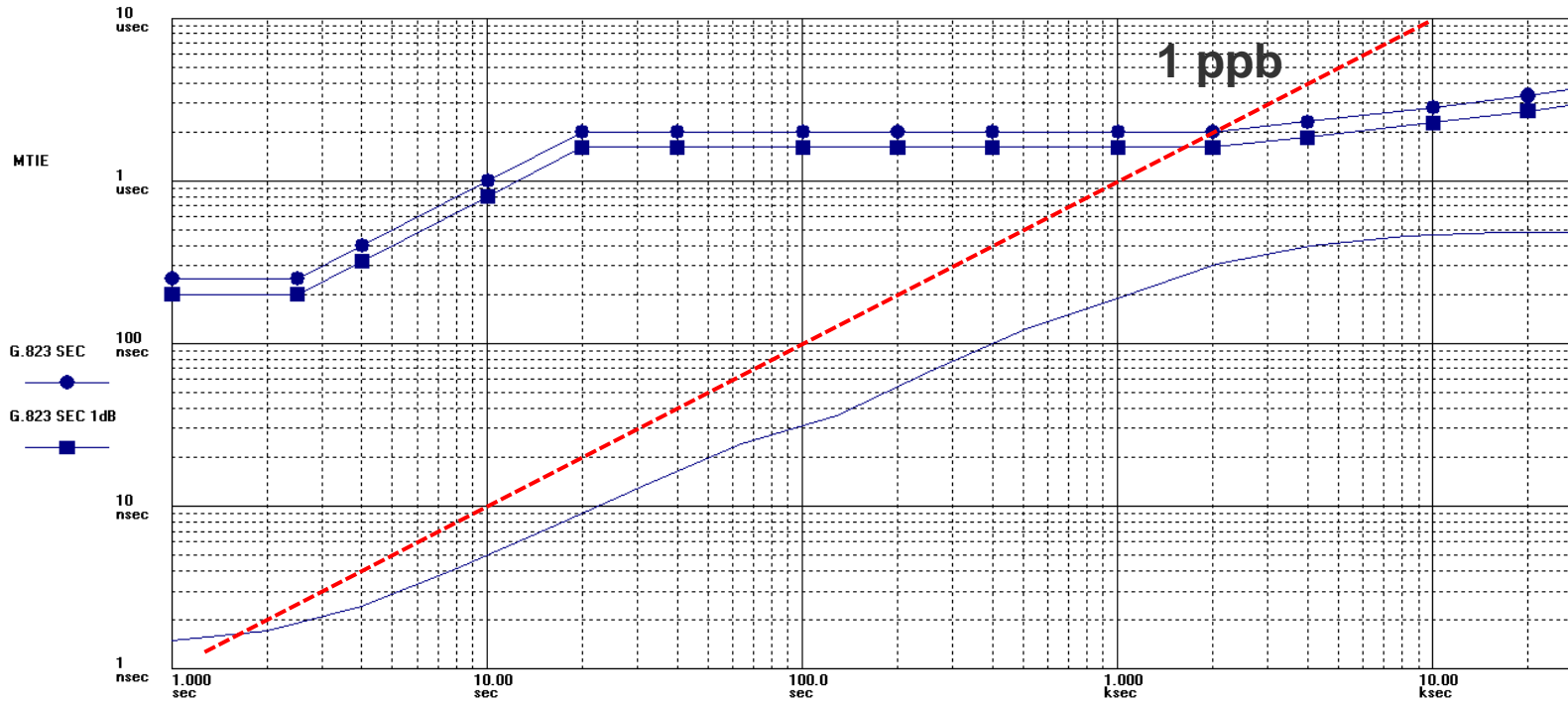TAZ

12 HOPS 1 BC (IMPL. A)

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=500.0 mHz; *7/21/2011 10:10:03 PM*; *7/21/2011 10:07:37 PM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 12600; Gate: 1 s; Stop: 12600; Total Points: 19603; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
TAZ-10mh
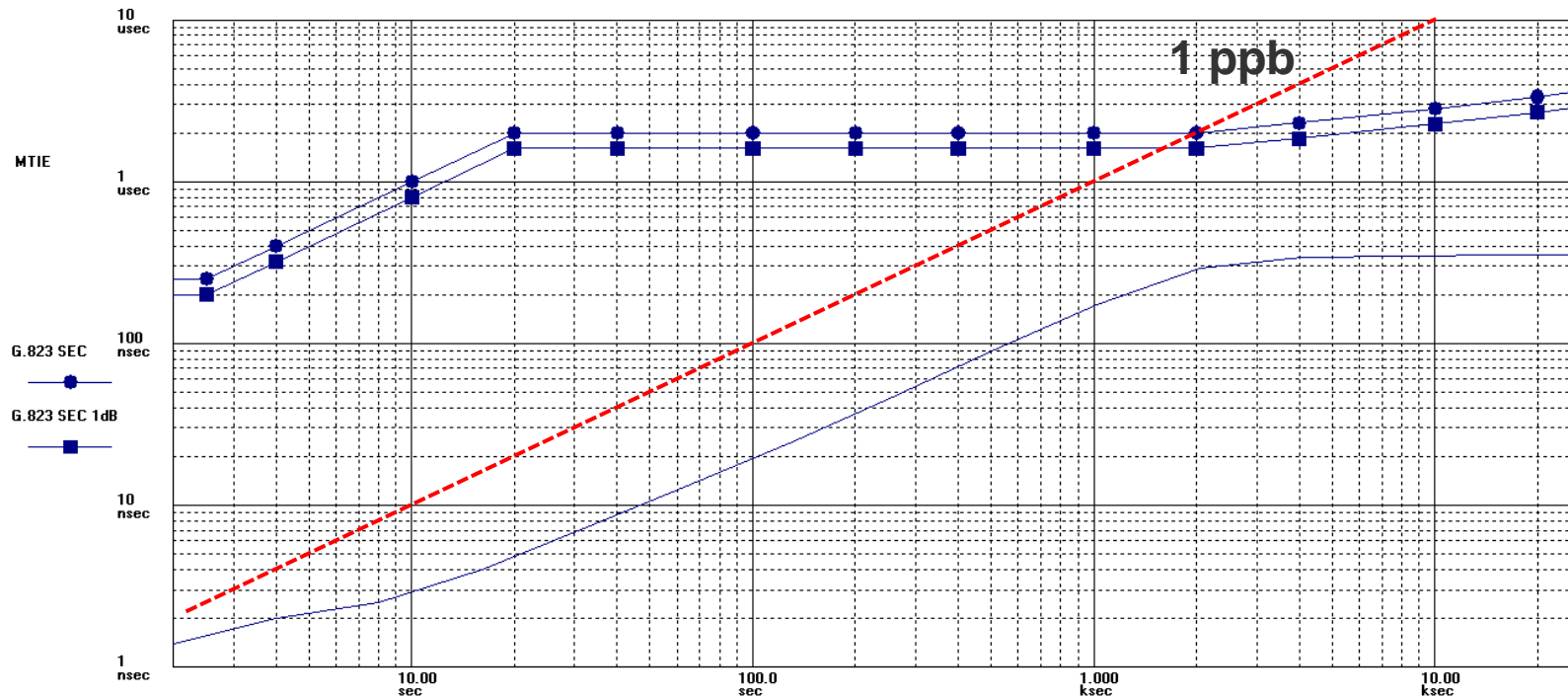
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Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.0 mHz; *8/7/2011 9:57:04 PM*; *8/8/2011 8:55:16 AM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 14400; Gate: 1 s; Stop: 14400; Total Points: 19714; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
TAZ-10mh
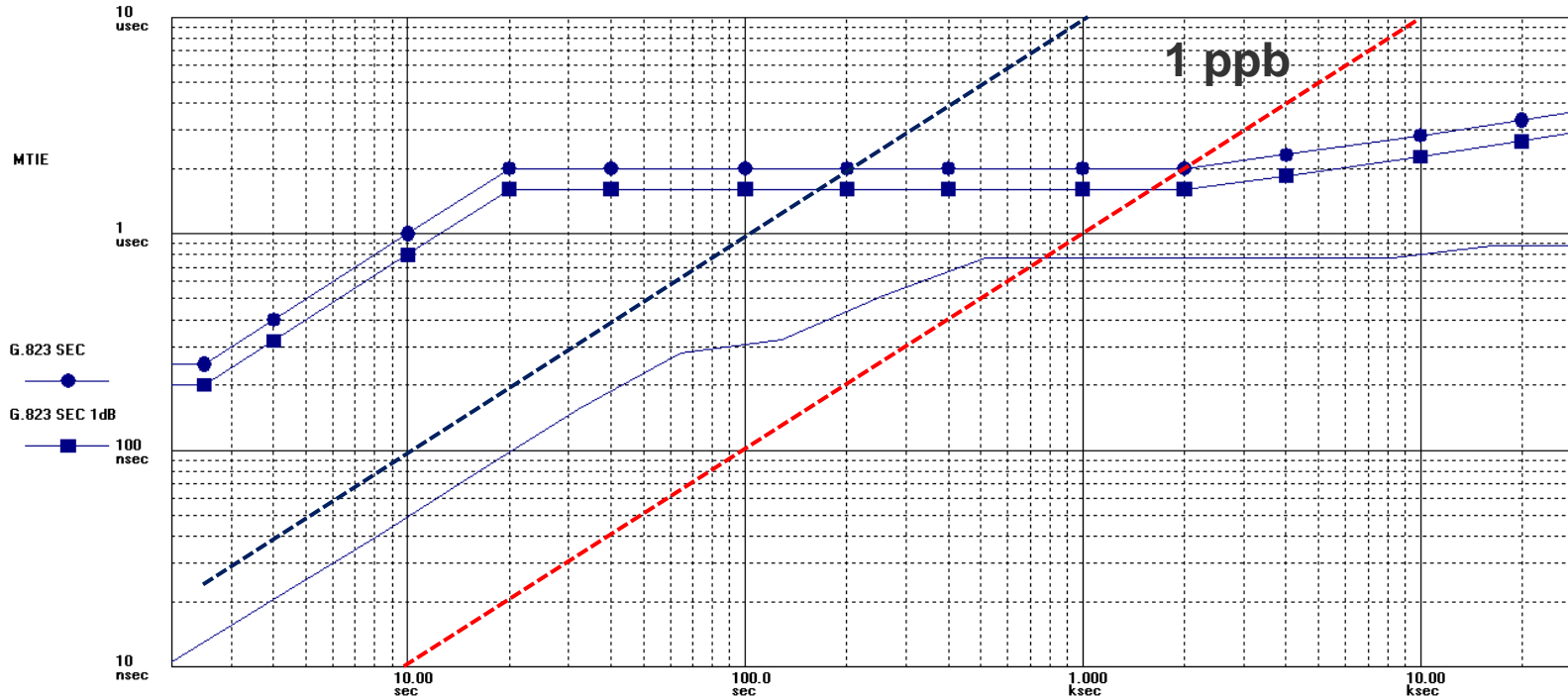
FFO (LSF)

Symmetricom TimeMonitor Analyzer   (file=5bc_taz_10mh_00001.dat)
Least square fit fractional frequency offset vs. time; N=110; 2011/08/28; 10:42:59
3 (magenta): HP 53132A; Test: 1;   TAZ-TIE;   Samples: 33113;   Gate: 1 s;   Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/08/28; 10:42:59
5 (cyan): HP 53132A; Test: 1;   TAZ-TIE;   Samples: 19603;   Gate: 1 s;   Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/07/21; 22:10:04
8 (grey): HP 53132A; Test: 1;   TAZ-TIE;   Samples: 19714;   Gate: 1 s;   Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/08/07; 21:57:05

12 hops, 1 BC Impl A

12 hops, 1 BC Impl B

6 hops, 5 BC

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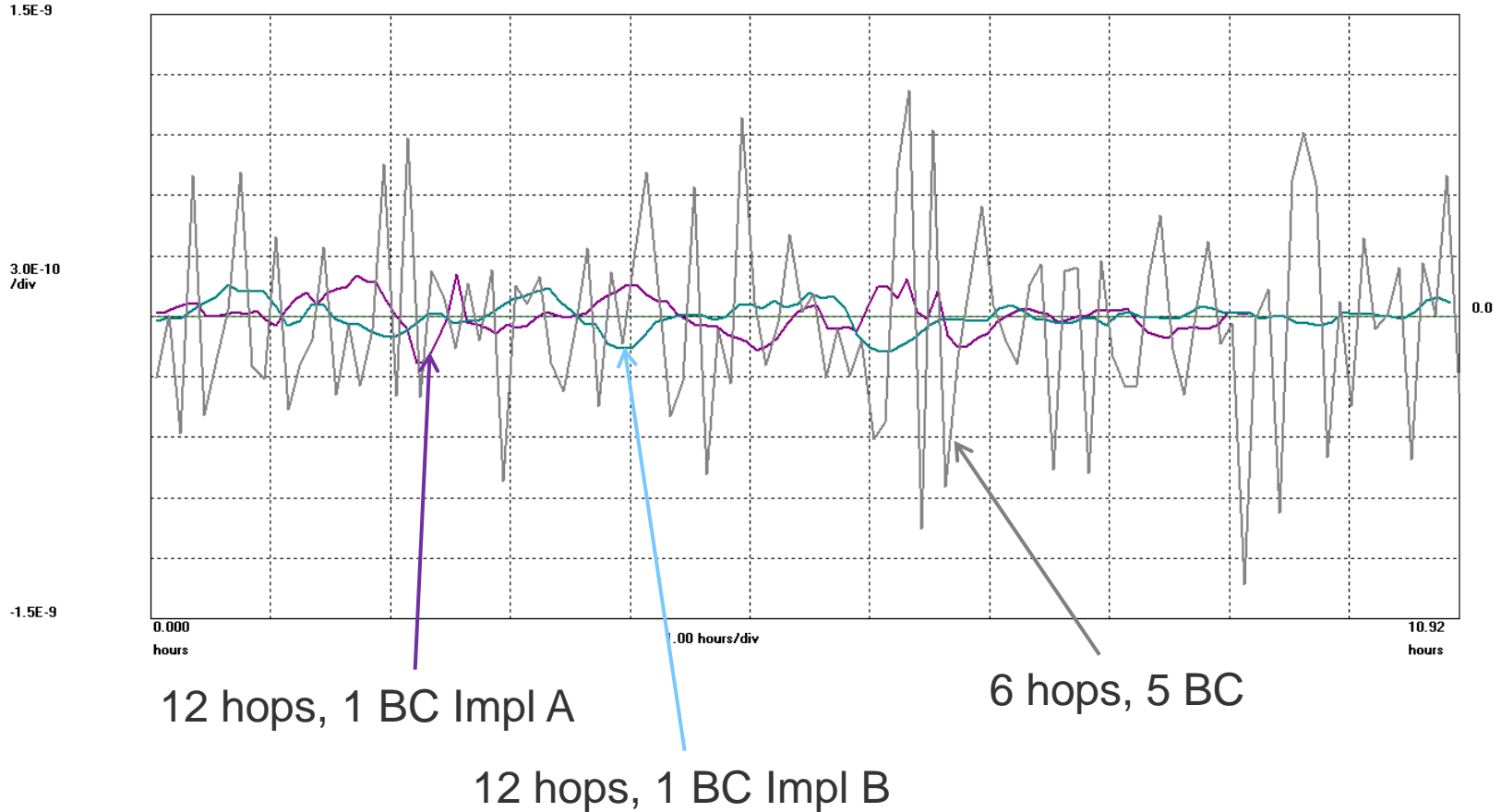
MTIE

Symmetricom TimeMonitor Analyzer   (file=5bc_taz_10mh_00001.dat)
MTIE; Fo=10.00 MHz; Fs=1.000 Hz; 2011/08/28; 10:42:59
2 (red): HP 53132A; Test: 1; TAZ-TIE; Samples: 33113; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/08/28; 10:42:59
4 (green): HP 53132A; Test: 1; TAZ-TIE; Samples: 19603; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/07/21; 22:10:04
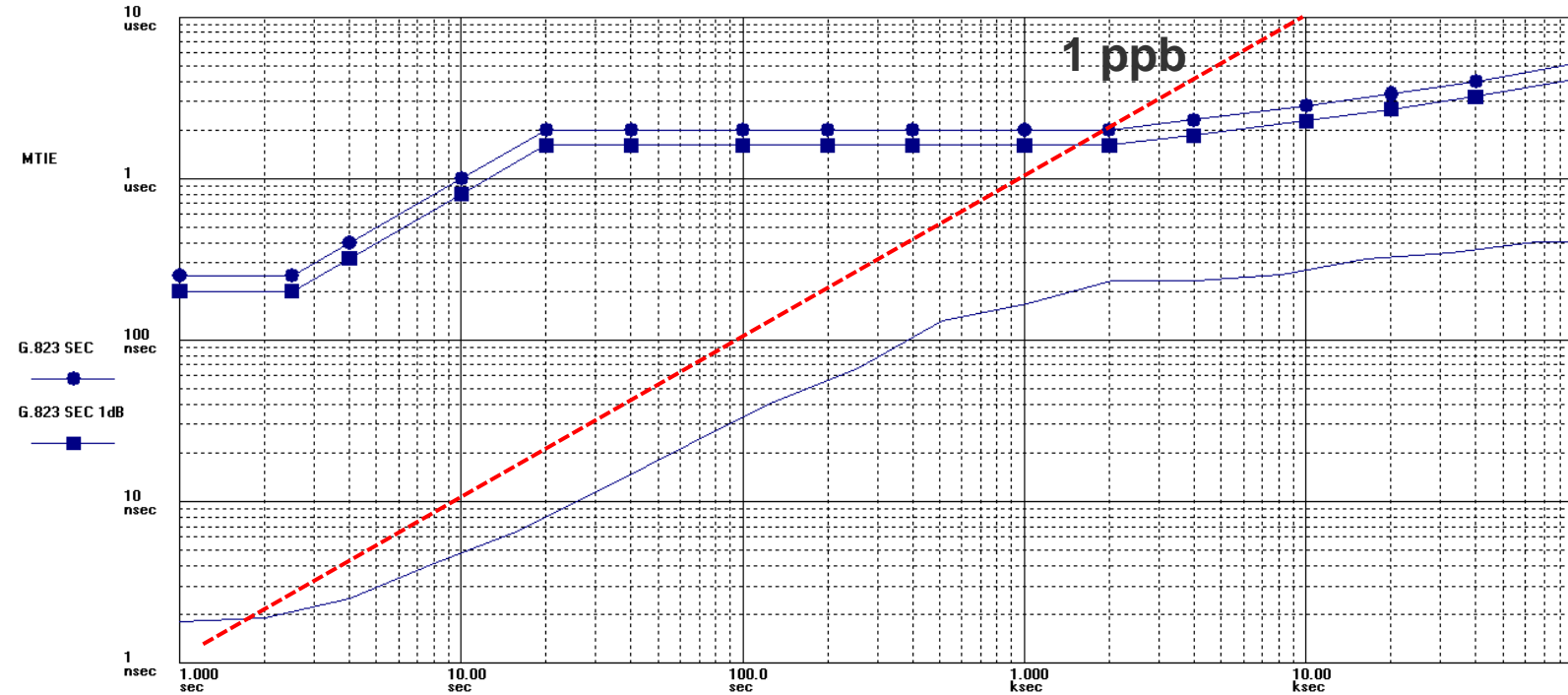7 (yellow): HP 53132A; Test: 1; TAZ-TIE; Samples: 19714; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; TAZ-10mh; 2011/08/07; 21:57:05

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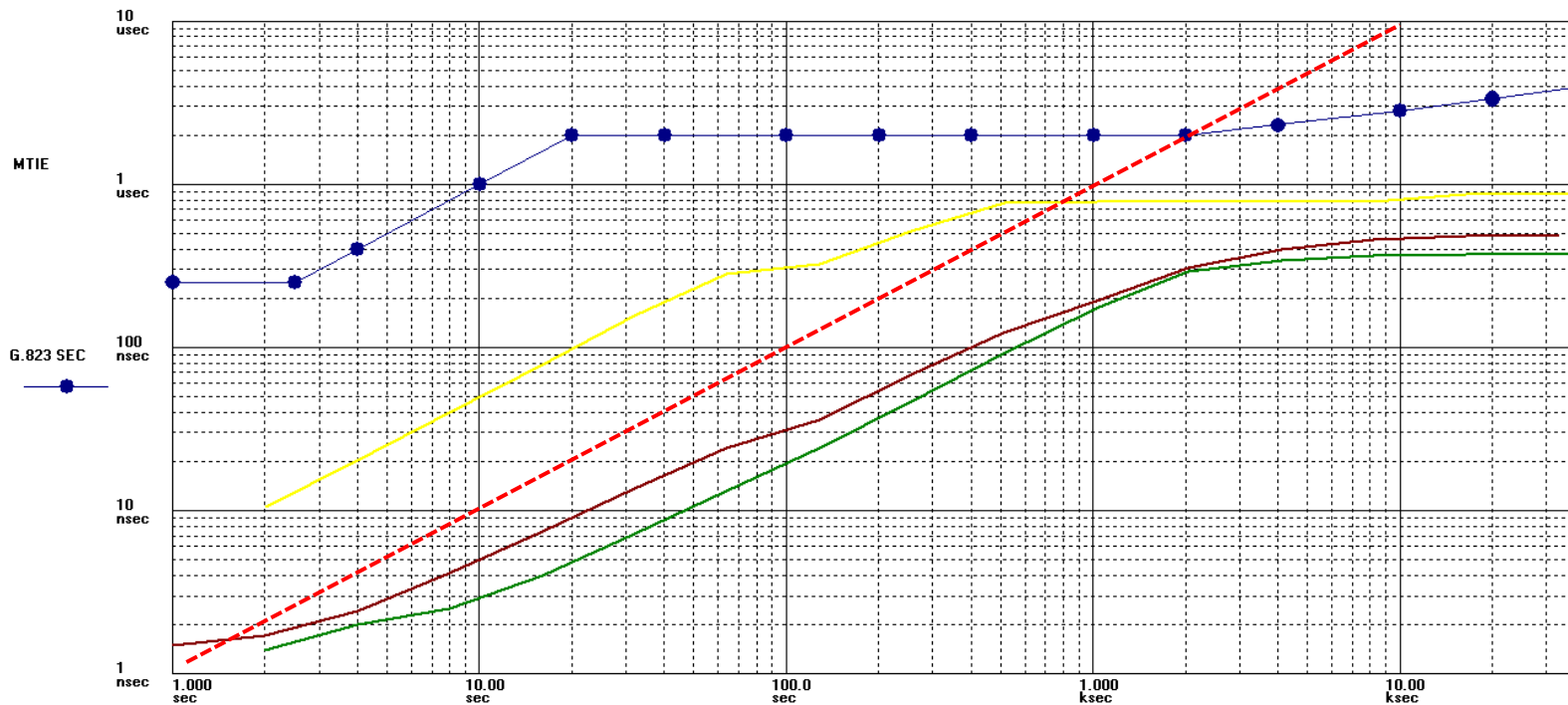
6 HOPS NO BC

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=1.000 Hz; *6/28/2011 3:06:47 PM*; *6/29/2011 5:20:02 PM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 90000; Gate: 1 s; Stop: 90000; Total Points: 94394; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
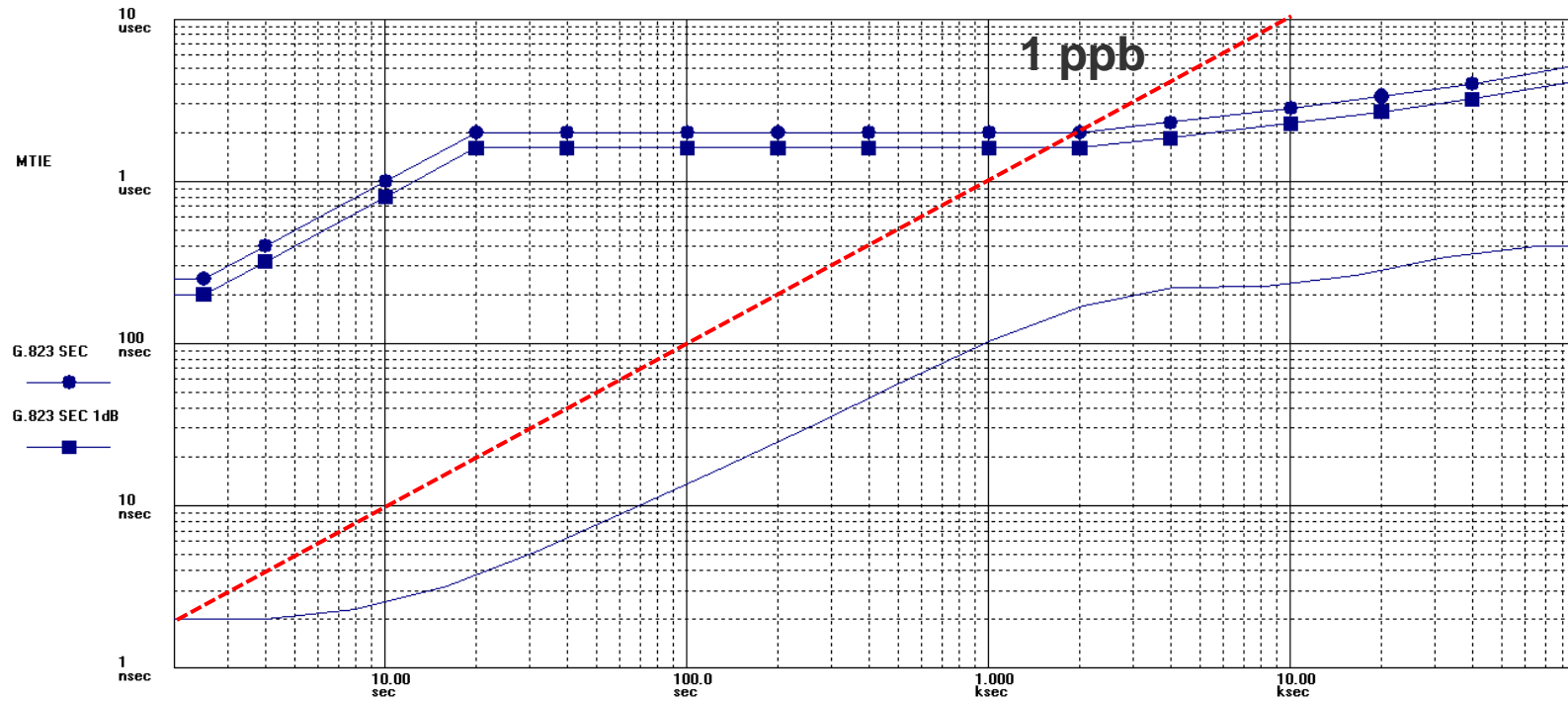TAZ

6 HOPS 1 BC (IMP A TAZ)

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.3 mHz; *7/25/2011 10:24:26 AM*; *7/26/2011 10:42:41 AM*;
HP 53132A; Test: 1;   TAZ-TIE;   Samples: 43689;   Gate: 1 s;   Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
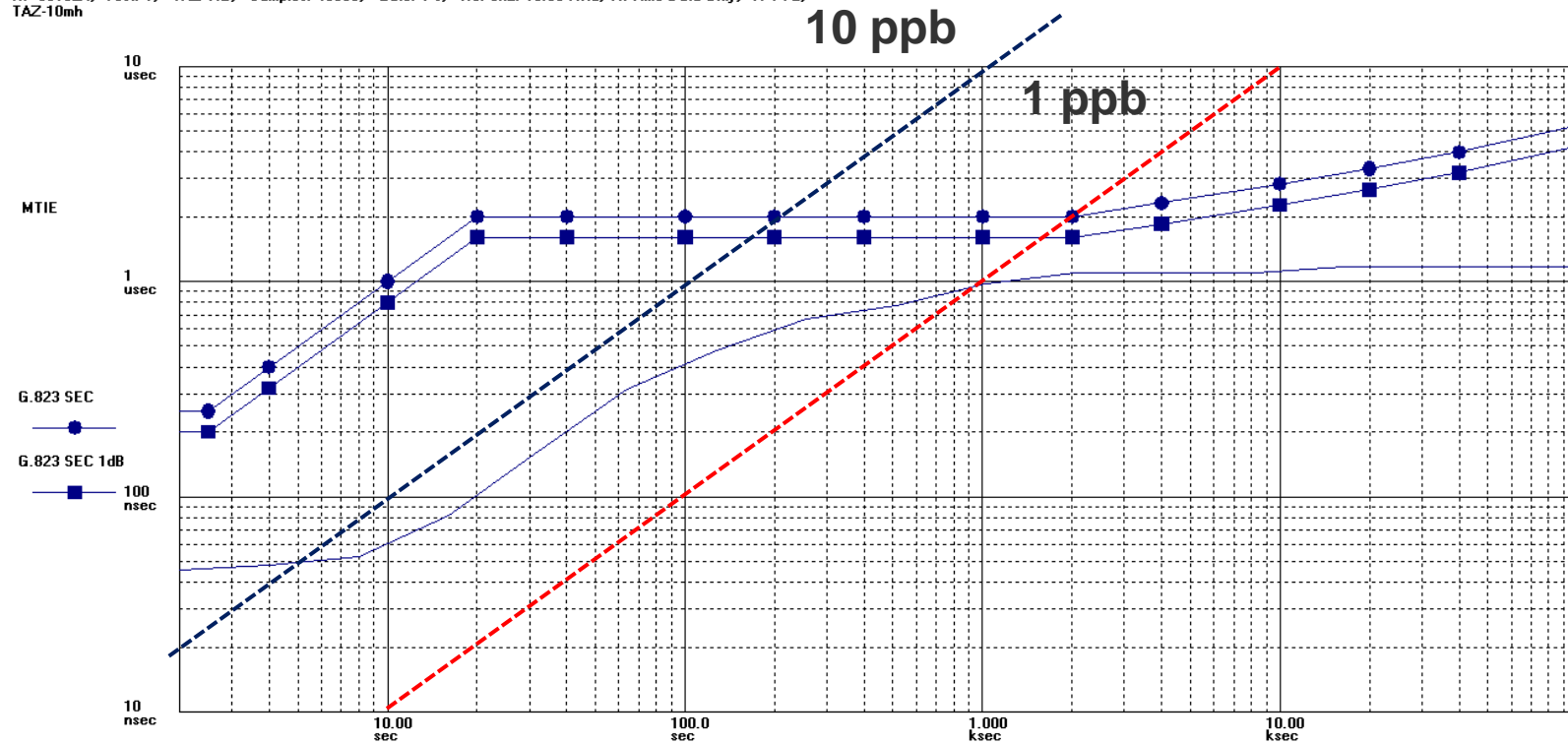TAZ-10mh
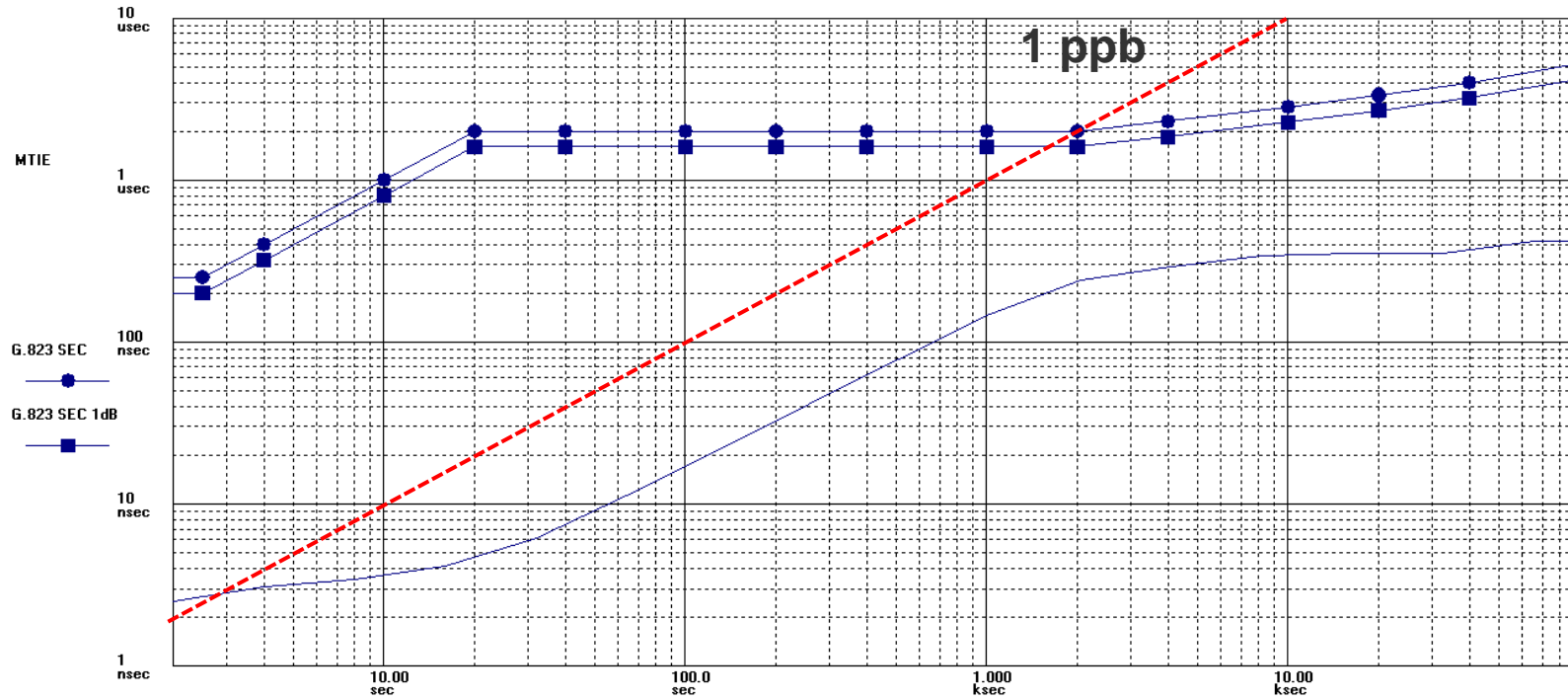
TEST CASE 14 TM1

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.5 mHz; *7/19/2011 7:58:20 PM*; *7/20/2011 8:16:13 PM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 43691; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
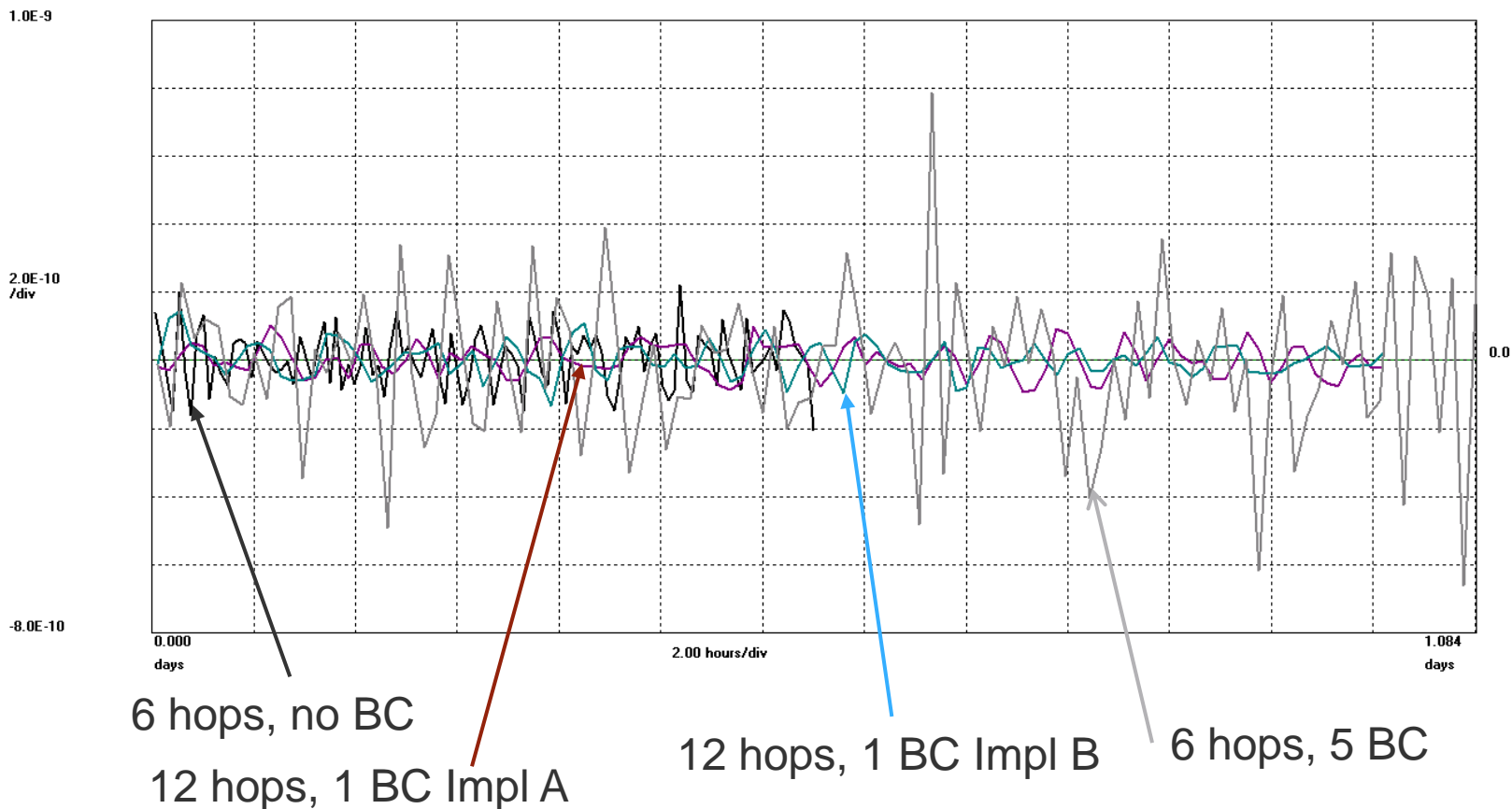TAZ-10mh

6 HOPS 5 BC

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.4 mHz; *8/12/2011 11:43:06 PM*; *8/14/2011 2:54:48 AM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 48890; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
TAZ-10mh

FFO (LSF)

Symmetricom TimeMonitor Analyzer   (file=00001.dat)
Least square fit fractional frequency offset vs. time; N=110; 2011/06/28; 15:06:48

6 hops, no BC

12 hops, 1 BC Impl A

12 hops, 1 BC Impl B

6 hops, 5 BC

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MTIE

Symmetricom TimeMonitor Analyzer   (file=00001.dat)
MTIE; Fo=10.00 MHz; Fs=1.000 Hz; 2011/06/28; 15:06:48

6 hops, no BC (blue)

12 hops, 1 BC Impl A (brown)

12 hops, 1 BC Impl B (green)

6 hops, 5 BC

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Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.5 mHz; *8/2/2011 9:03:20 AM*; *8/3/2011 11:04:08 AM*;
HP 53132A; Test: 1;   TAZ-TIE;   Samples: 45000;   Gate: 1 s;   Stop: 45000;   Total Points: 46778;   Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
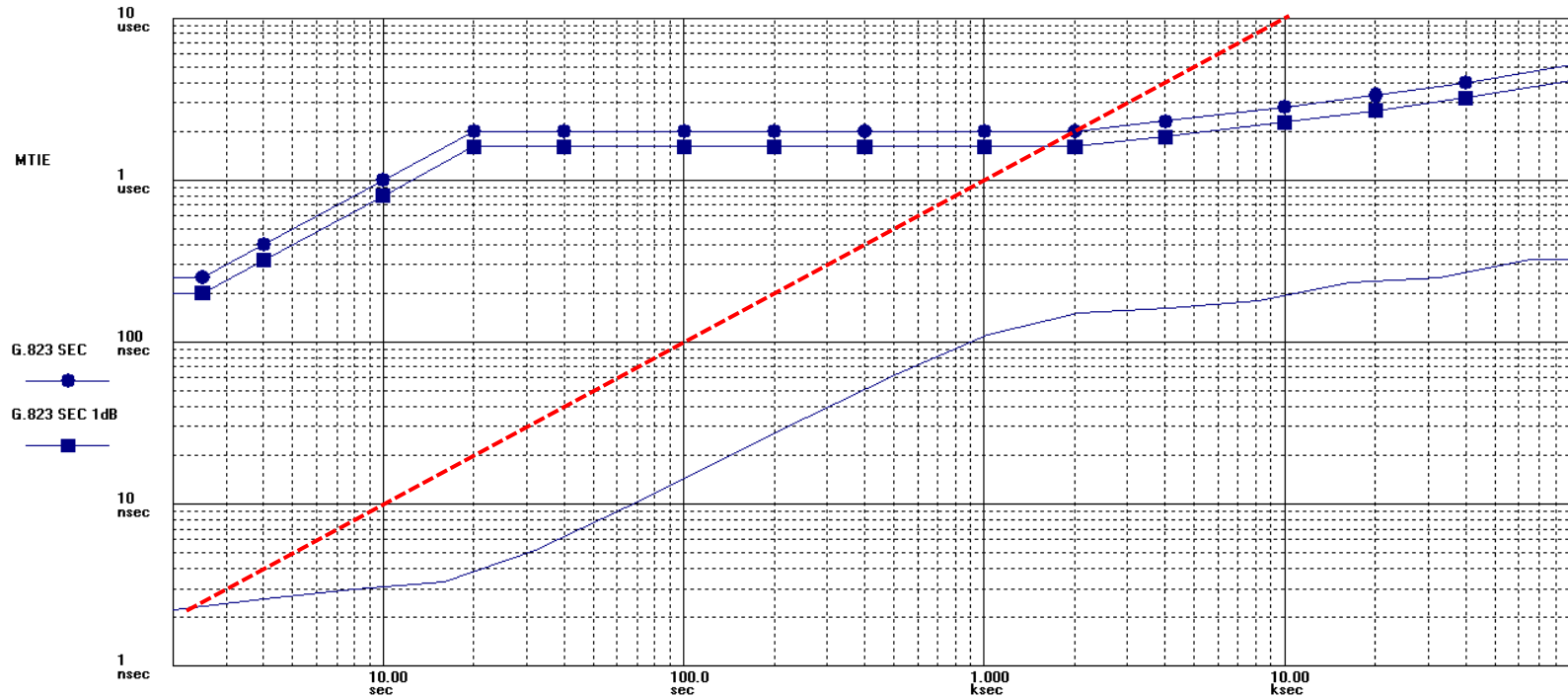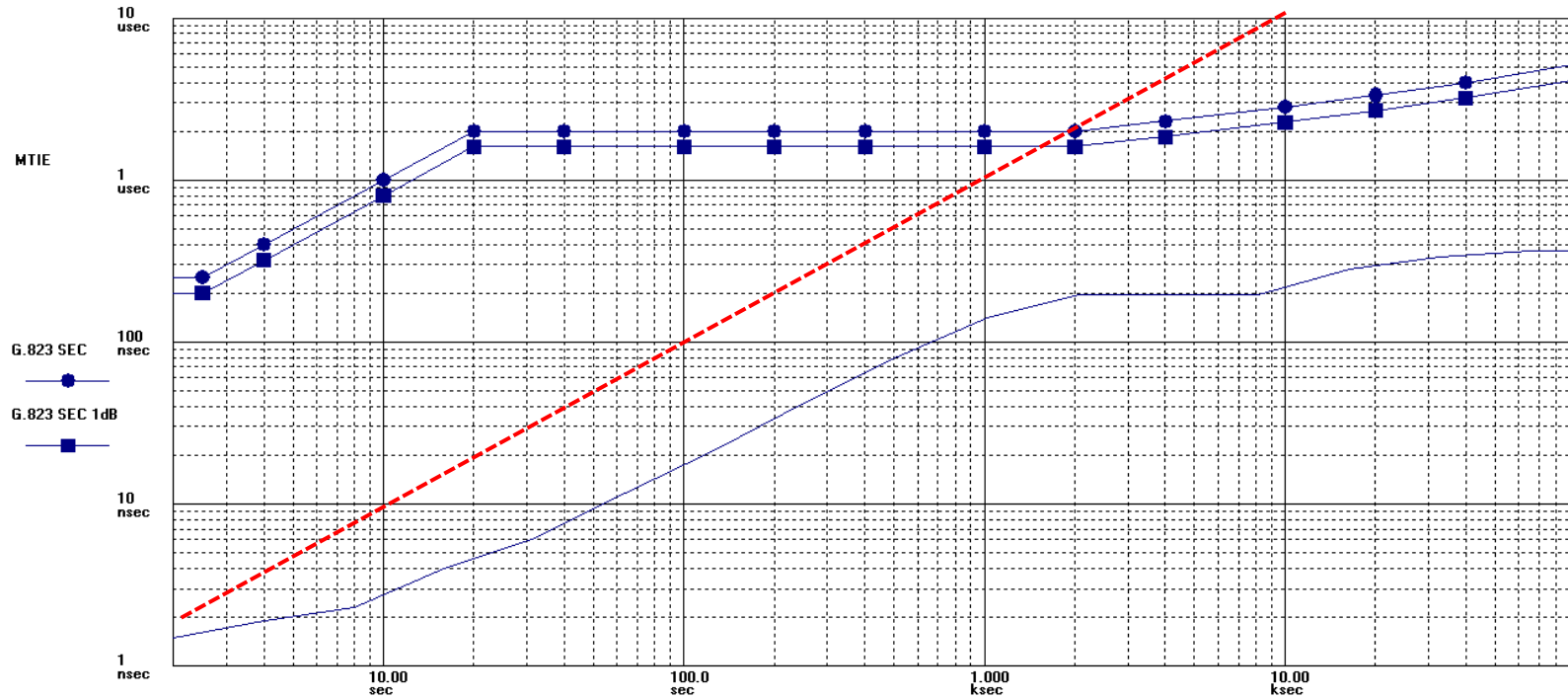TAZ-10mh

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12 HOPS 1 BC (IMP A)

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=500.0 mHz; *7/23/2011 7:54:45 PM*; *7/24/2011 10:16:35 PM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 45000; Gate: 1 s; Stop: 45000; Total Points: 47425; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
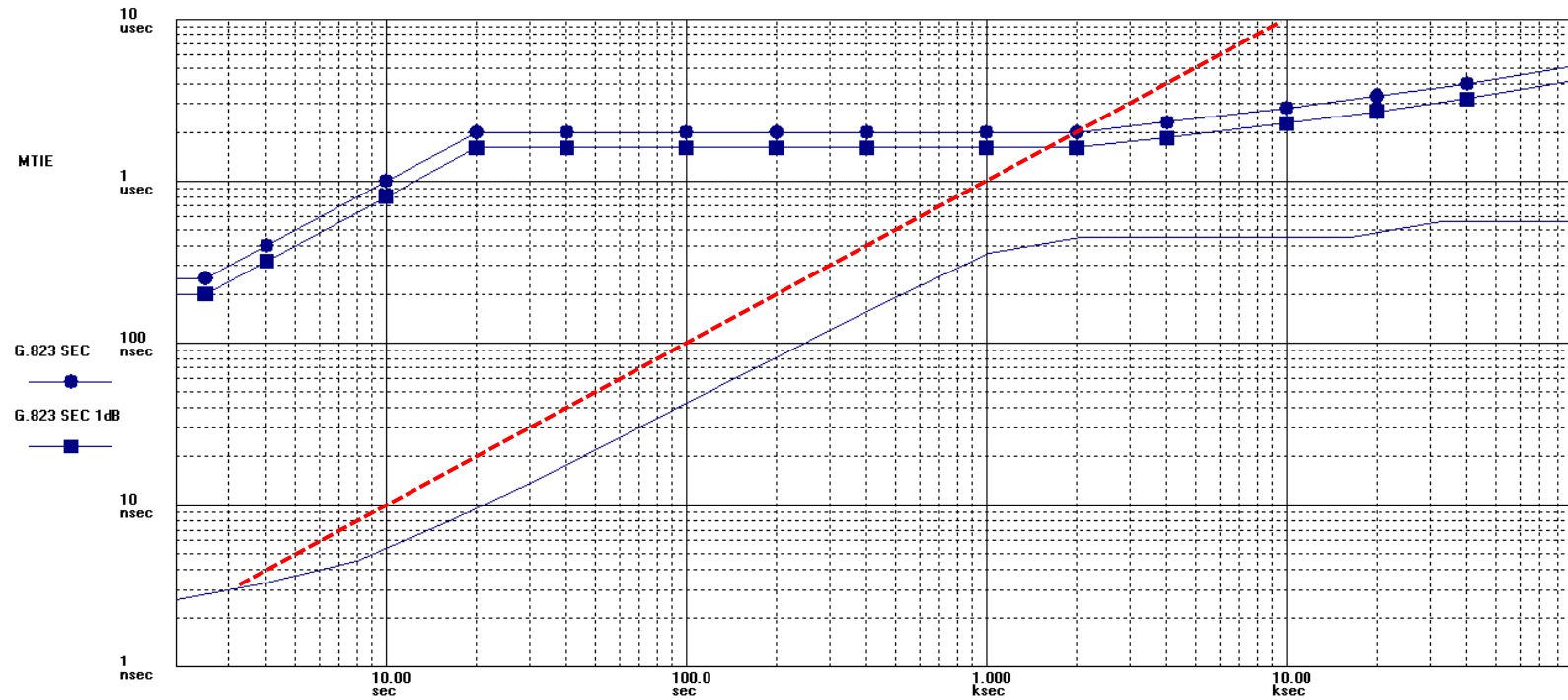TAZ-10mh

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TEST CASE 14 TM2

12 HOPS 1 BC (IMPL B)

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.5 mHz; *7/14/2011 9:41:05 PM*; *7/15/2011 11:01:44 PM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 45573; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
TAZ-10mh

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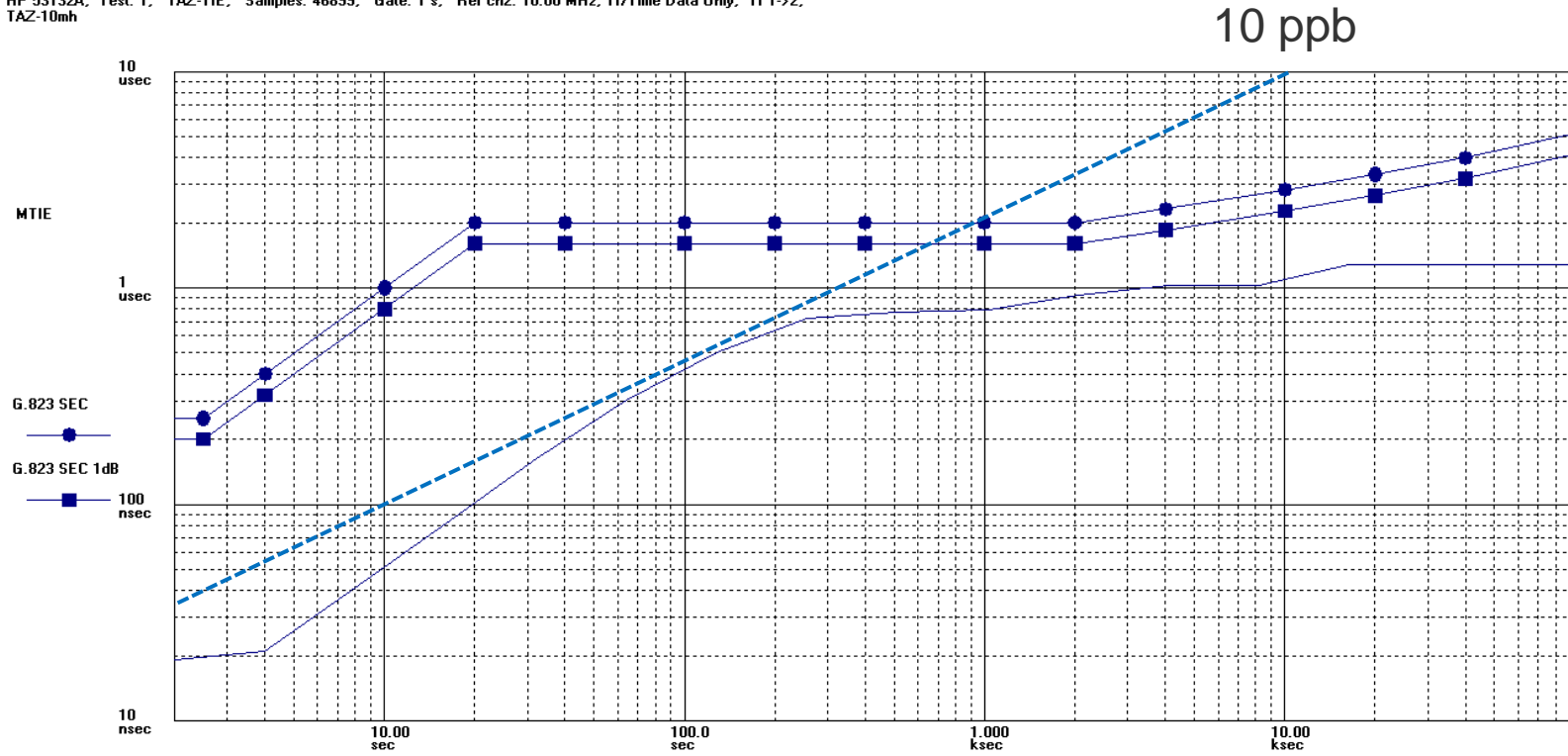JUNIPER
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6 HOPS 5 BC

Symmetricom TimeMonitor Analyzer
MTIE; Fo=10.00 MHz; Fs=499.2 mHz; *8/10/2011 10:54:44 AM*; *8/11/2011 1:00:26 PM*;
HP 53132A; Test: 1; TAZ-TIE; Samples: 46899; Gate: 1 s; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2;
TAZ-10mh

10 ppb

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SUMMARY FFO

Network topology	Test case 13 (FFO ppb)	Test case 14 (FFO ppb)
6 hops Timing Unaware NEs	-0.8 to 0.95	-.1.8 to +1.6
12hops with 1 BC, rest Timing Unaware NEs (Implementation A)	-0.7 to 0.8	-0.7 to +0.7
12hops with 1 BC, rest Timing Unaware NEs (Implementation B)	-0.7 to 0.9	-0.7 to 0.9
6 hops, 5 Boundary clocks	-8.0 to 5.4	-5 to 5

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SUMMARY FFO

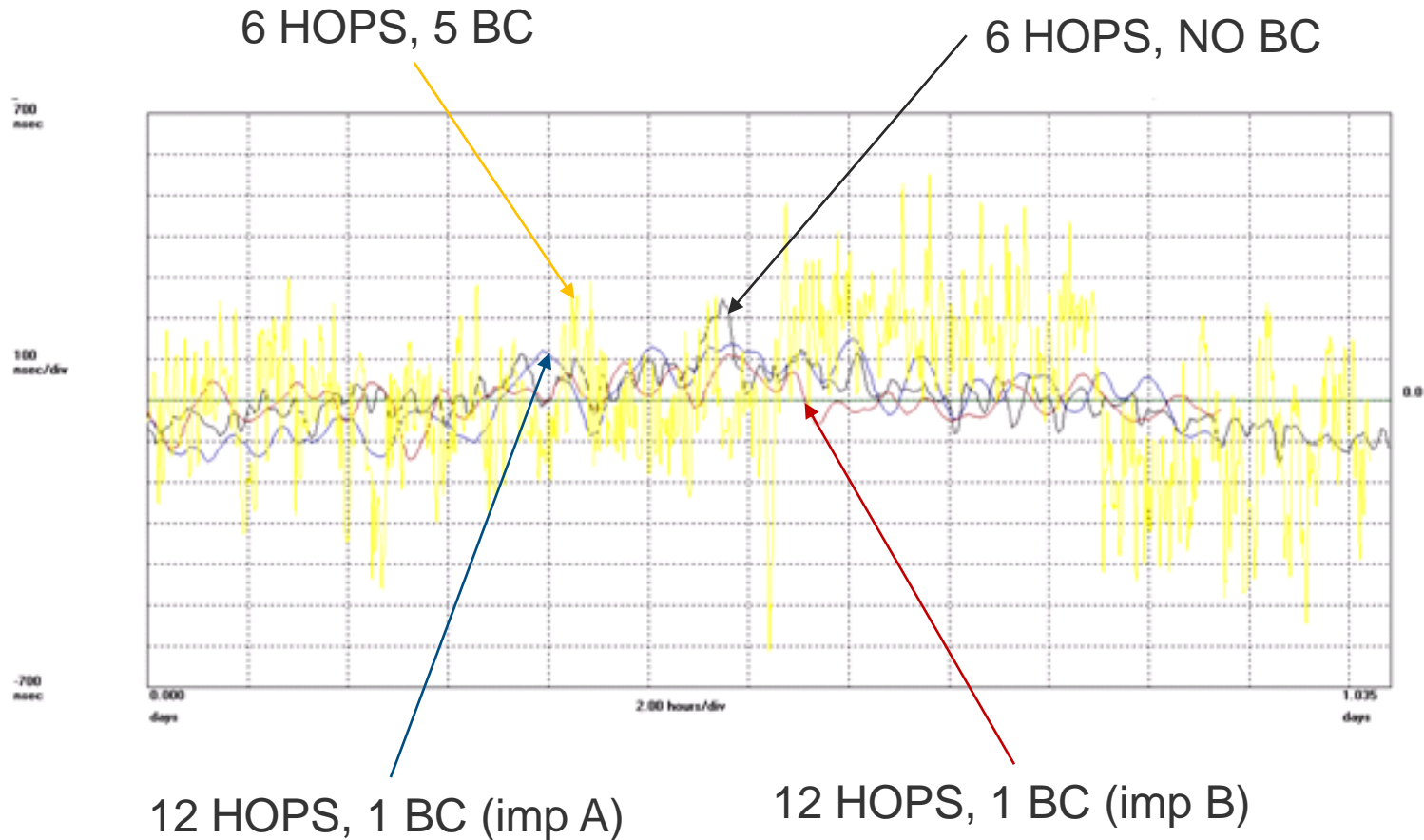| Network topology	Test case 13 (FFO ppb)	Test case 14 (FFO ppb)
6 hops Timing Unaware NEs	-1.8 to +1.6	-1.0 to +2.2
12hops with 1 BC, rest Timing Unaware NEs (Implementation A)	-0.7 to 0.7	-0.75 to +0.7
12hops with 1 BC, rest Timing Unaware NEs (Implementation B)	-0.7 to 0.9	-0.8 to 1
6 hops, 5 Boundary clocks	-5 to 5	-9.6 to 20

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PHASE (TIE)

6 HOPS, 5 BC

6 HOPS, NO BC

12 HOPS, 1 BC (imp A)

12 HOPS, 1 BC (imp B)

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Some Highlights

HIGHLIGHTS

Some Observations from the test data

Frequency:

On a 6 hop network frequency variation : ~ 2ppb

The same accuracy to be extended to a 12 hop network with a Centrally located Boundary clock

Phase:

It is possible to deliver a phase with accuracy of 200 to 250 ns
- Across a12 hop network

"More Boundary clocks are not necessarily good"

"Proper placement of network elements is important"

Suggestions

SUGGESTIONS

Systems with frequency requirements

- A well engineered network of 6 hops (may be 8) hops can deliver frequency with accuracy of about 2 ppb

- For larger networks a BC should be introduced every 6 to 8 hops

Systems with Phase requirements

Limited data suggests -In well engineered systems (with asymmetry compensated)

Phase accuracy of +/- 200 to 250nS may be achieved over a network of 12 hops with BC at every 4 to 6 hops

* system needs to be characterized before commissioning !!

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Ending Remarks

Presented some Experimental data

Future work

    Compare Simulation and Analytical results with Experimental data

    Study the phase delivery behavior in greater detail.

Significant amount of work is being done in this field
- Propose development of " PTP deployment Handbook"

<div align="center">(on the lines of OTN handbook)</div>

    (perhaps under auspices of IEEE/ICAP or ITU)

<div align="center" style="color:blue">Our collective Knowledge should benefit all !!</div>

Questions

everywhere