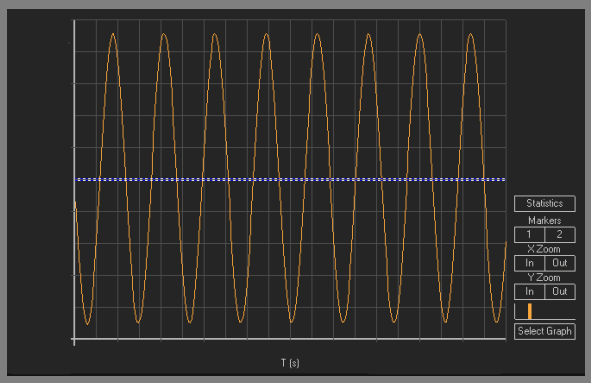
G.8262 SyncE conformance testing

Proving SyncE compliance as per ITU-T G.8262 using Paragon-X



The ITU-T G.8261 and G.8262 standards specify compliance requirements for SyncE Jitter and Wander performance to ensure the interoperability of network equipment within a telecoms network.

This application note details how the Calnex Paragon-X can be used to prove compliance to G.8262 and provides procedures to measure noise generation, tolerance and transfer, packet layer transient response and holdover performance of ethernet equipment

Contents

1 Hardware and Software Required

- Paragon-X

  Option 111 – 10GbE interface (optional)
  Option 213 – SyncE Wander and ESMC
  Option 223 – G.8262 MTIE and TDEV Wander Generation
  Option 207 or 217 - SyncE Jitter testing (1GbE) (optional)
  Option 208 or 218 - SyncE Jitter testing (10GbE) (optional)
  Software version: X.10.23.22 or later

- Synchronization (reference) Frequency Source.

2 Connecting an EEC to Paragon-X

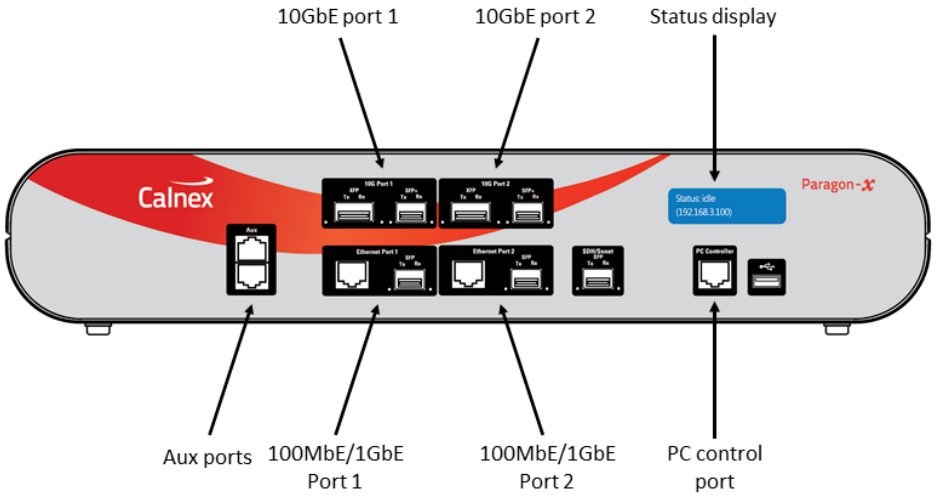


Figure 1: Paragon-X Front Panel Connections

The front panel of Paragon-X provides the following interfaces:

- 100MbE electrical or optical (SGMII SFP)
- 1GbE electrical or optical (SFP) – with option 110 fitted
- 10GbE optical (XFP or SFP+) – with option 111 fitted

There are two reference input connections on the Paragon-X rear panel, as shown in Figure 2:

- BNC with 75Ω impedance
- Bantam connector with 100 Ω impedance
  - 3 pole bantam jack
  - 4.39mm diameter tip; Positive, Ring; Negative, Sleeve; Ground

Paragon-X accepts the following reference clocks which should be applied to the appropriate Reference Input:

- 2.048MHz / 10MHz
- E1 (2.048Mb/s)
- DS1 (T1) (1.544Mb/s)

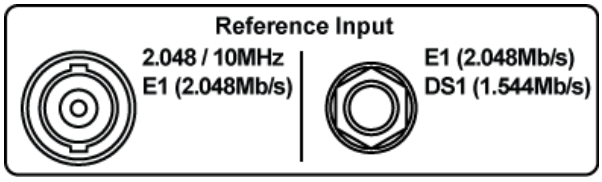
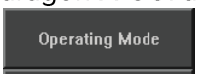
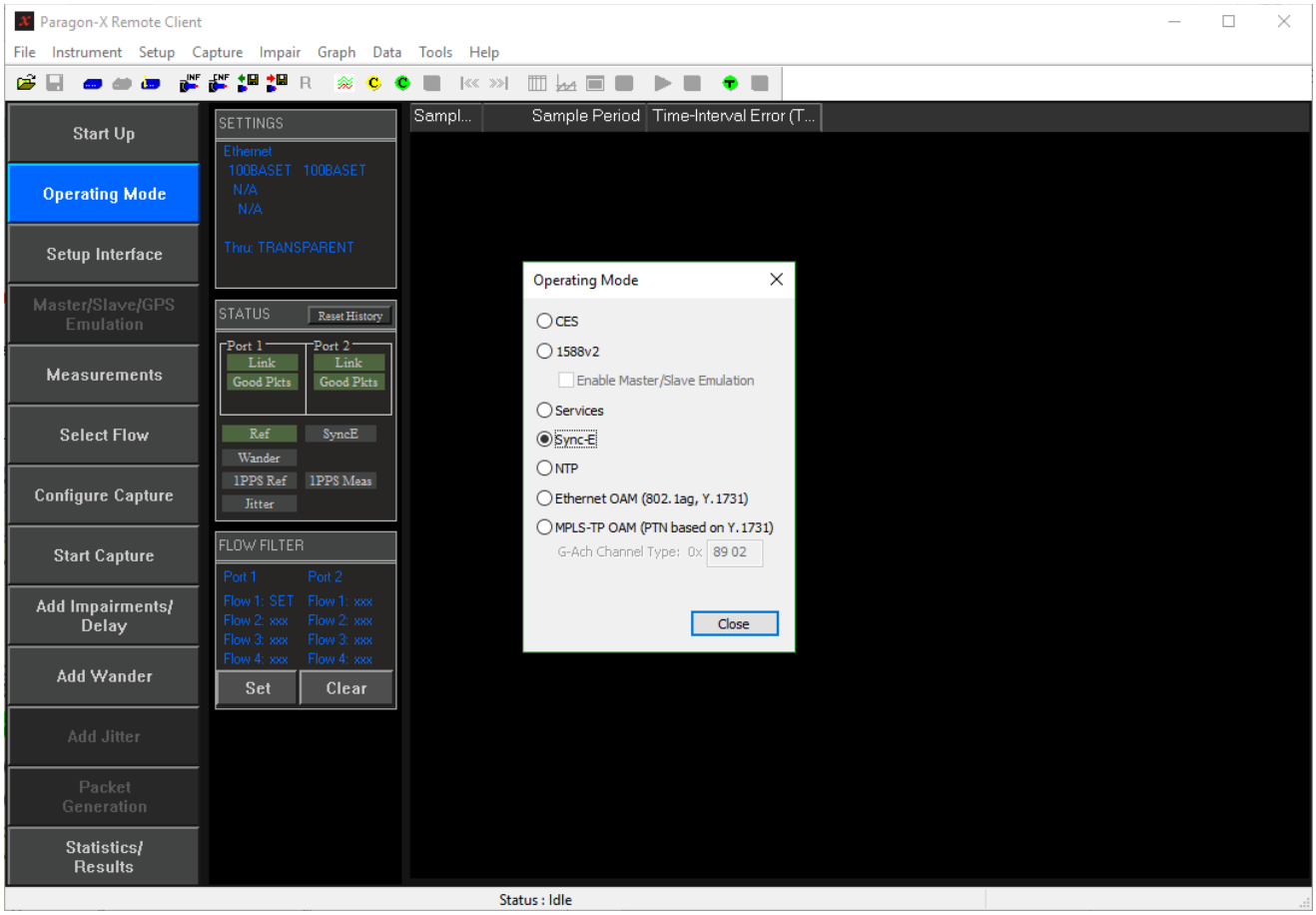


Figure 2: Paragon-X rear panel Reference Inputs

3 How to Configure the Paragon-X for All G.8262 Tests

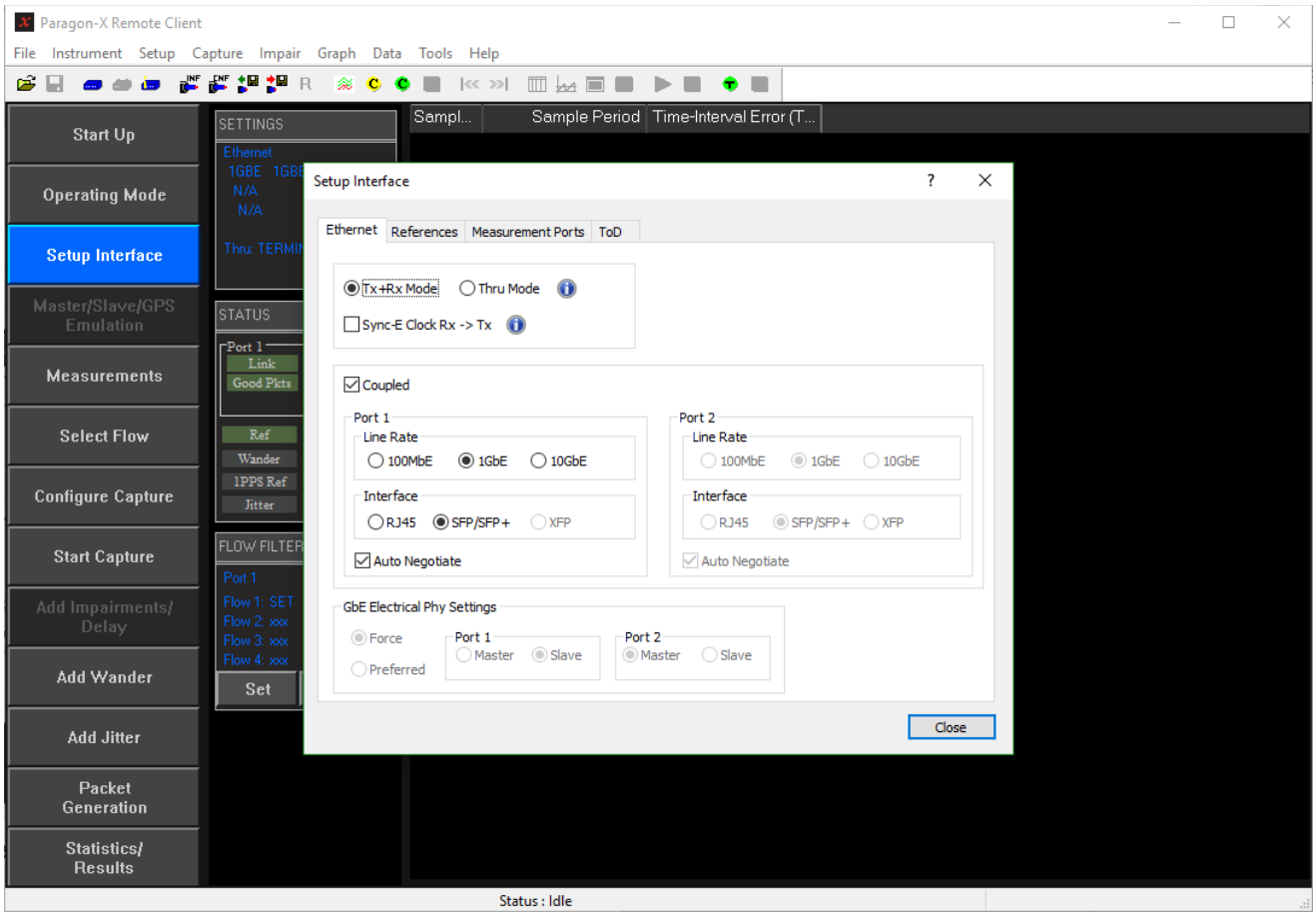
a) Verify the physical connections have been completed as detailed in the relevant test section
b) Start the Paragon-X GUI and connect to Paragon-X using ***Instrument - Connect***
c) Select the 

button.



d) Select ***Sync-E*** then select ***Close***
e) Click 

f) Select ***Tx+Rx mode***

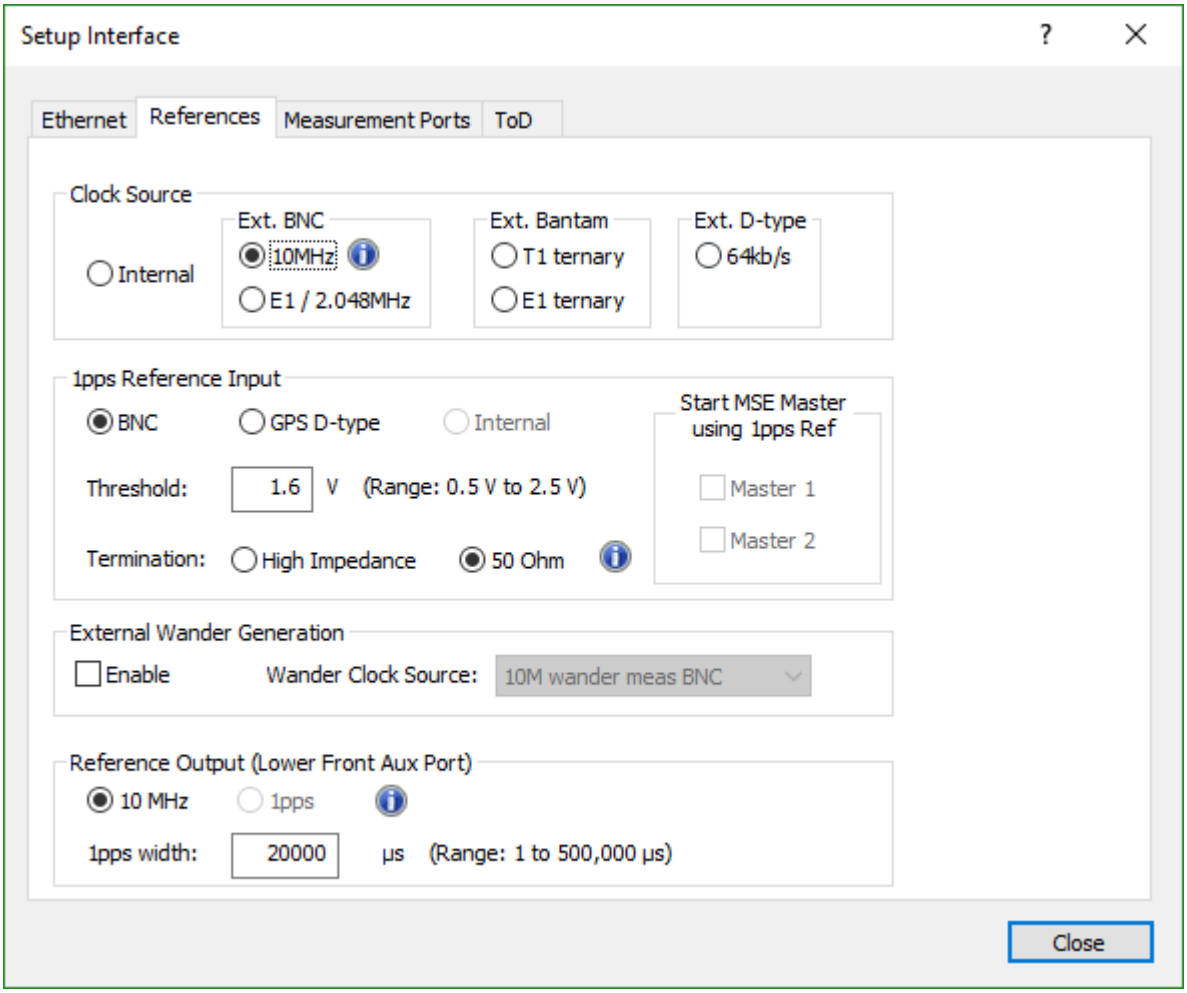


g) Verify that the ***SyncE Clock Rx -> Tx*** is **not** checked

h) Select the appropriate line rate and interface type for ports 1 and 2.

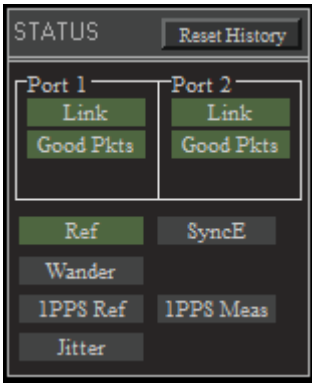
NOTE: If using SFP, XFP or SFP+ optical transceivers, they must be inserted into both ports 1 and 2 of Paragon-X before the selection can be made.

i) Select the ***References*** tab and enable the desired reference clock source.



j) Select the ***Close*** button to close the ***Setup Interface*** window.

Note: once SyncE mode is selected, the Paragon-X GUI ***SyncE*** indicator will be grey. This indicates that the ***SyncE Rx -> Tx*** box is unchecked and that Paragon-X is using its internal or an external clock.

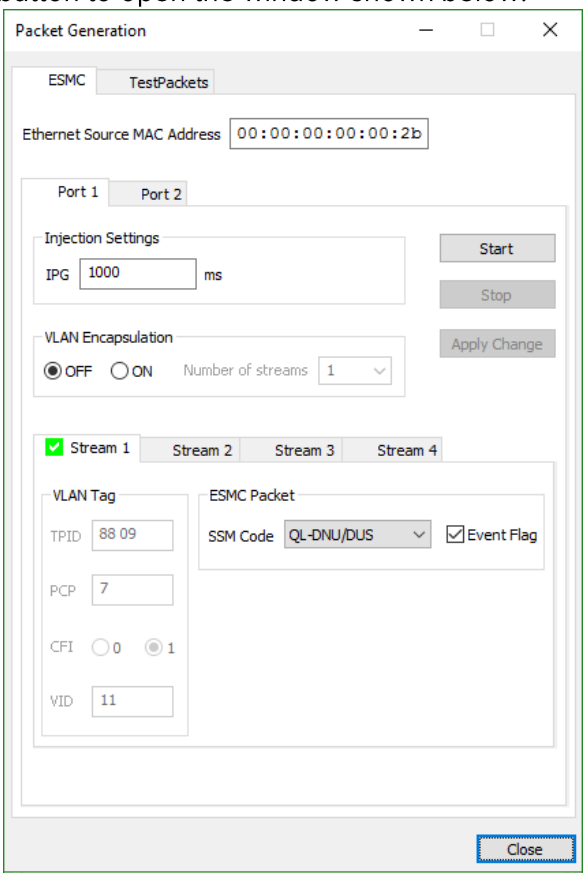


3.1 ESMC Generation

Ethernet Synchronization Message Channel (ESMC) is a point-to-point protocol which transmits Synchronization Status Message (SSM) information by using ESMC Protocol Data Units (PDUs). These PDUs are normally transmitted once per second on the Slow Protocol Channel and contain the Quality Level (QL) of the transmitting EEC clock. The receiving EEC uses this QL to select the best quality clock available to it. The EEC then regenerates an ESMC PDU with the appropriate QL TLV value to indicate the quality of the clock being transmitted to the next EEC. If the EEC supports ESMC, it is possible for Paragon-X to use ESMC to indicate if the EEC switches its clock reference or goes into holdover.

Paragon-X can generate ESMC messages on both ports 1 and 2. For G.8262 conformance testing, ESMC messages are generated on port 2 with a user-defined Quality Level (QL) such as PRC.

a) Configure and enable the generation of ESMC messages by clicking the Packet Generation button to open the window shown below:



b) Select the ***Port 2*** tab (port 2 will be the output from Paragon-X and input to EEC)

c) Ensure the ***IPG*** (inter-packet gap) rate is set to 1000ms. This configures ESMC packets to be sent once per second.

d) Use the ***ESMC Packet*** drop-down list to set ***SSM Code*** to QL-PRC, which will inform the EEC that the Paragon-X clock is of PRC quality

e) Click Start to initiate packet generation, then Close

f) The ***Packet Generation*** button will show red 

to indicate Paragon-X is generating ESMC packets

NOTE: After making any setup changes to Paragon-X, ensure the EEC has had time to settle before making any measurements.

4 Measuring frequency accuracy – G.8262 Section 6

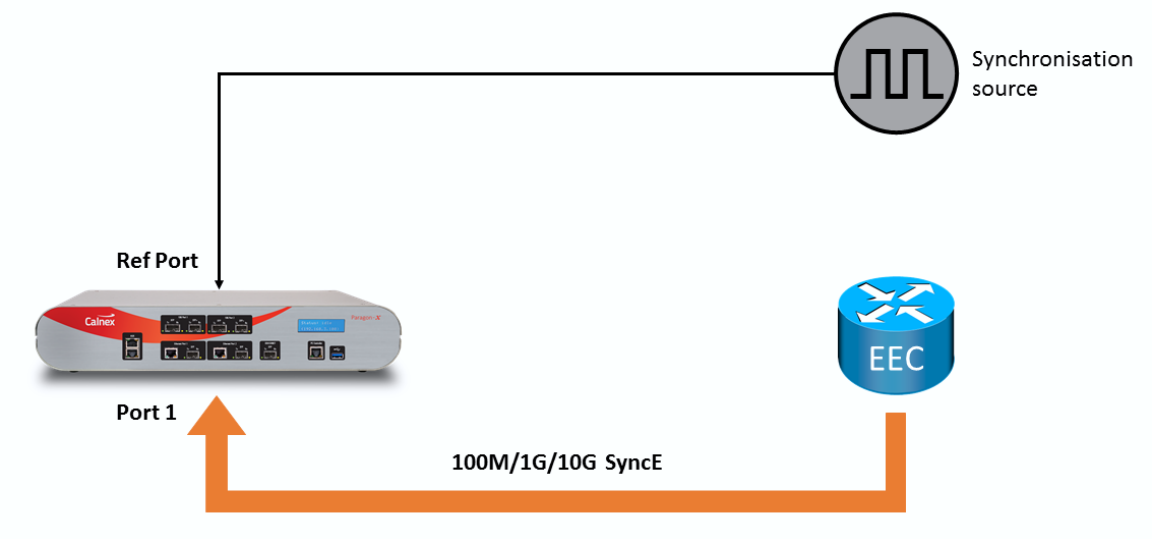


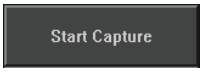
Figure 3: Frequency accuracy test set-up

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	Free run	±4.6 ppm	Recommend to test for an hour, longer if close to limits
EEC Option 2	Hold over	±4.6 ppm	Recommend to test for an hour, longer if close to limits

4.1 Measurement Setup

a) Connect the EEC to Paragon-X as shown in Figure 3.
b) Ensure Paragon-X is configured as per Section 3.

4.2 Measurement Process

a) Select the 

button to start measurement.

b) To manually stop the measurement after the desired period, select the 

button.
c) Paragon-*X* will display the measured ppm frequency accuracy at the bottom of the graph as shown in Figure 4 below.

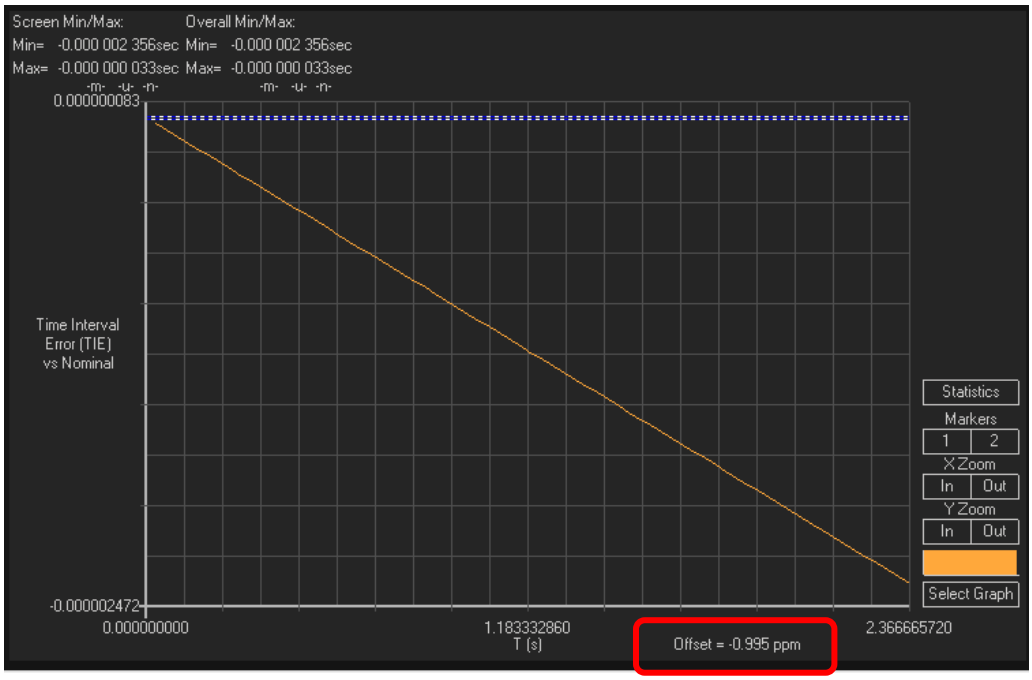


Figure 4: Frequency Accuracy Measurement

5 Pull-In, Hold-In and Pull-Out Ranges – G.8262 Section 7

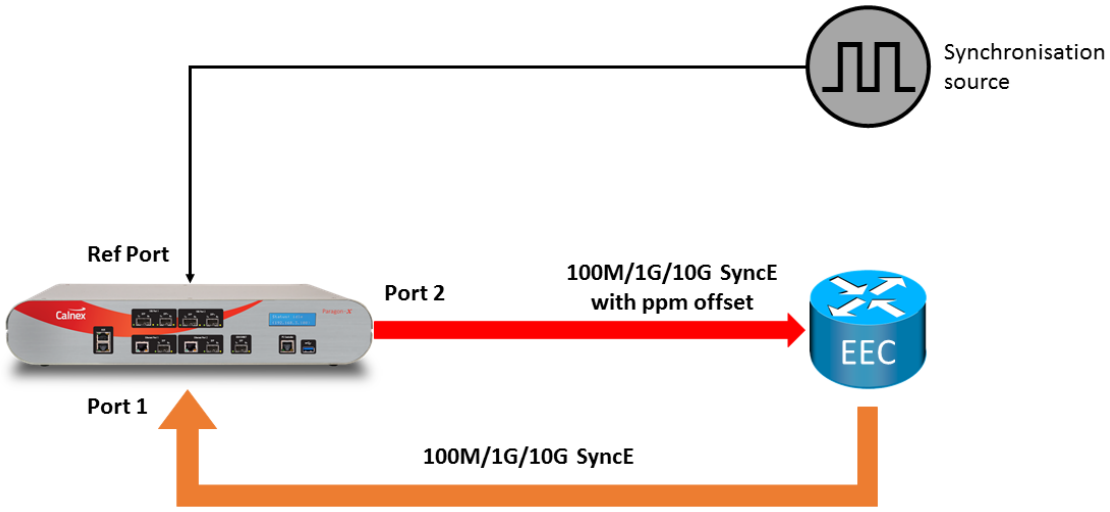


Figure 5: Pull-in, pull-out and hold-in test set-up

5.1 Pull–In Range - G.8262 Section 7.1

The Pull-in range is defined as the largest offset between a slave clock's reference frequency and a specified nominal frequency within which the slave clock will achieve locked mode.

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1 and EEC Option 2	Apply a large frequency offset and ensure EEC is in holdover. Reduce offset until EEC locks.	EEC starts unlocked with large offset applied EEC locks before offset reaches ±4.6ppm	Lock may also be monitored by using ESMC

5.2 Hold–In Range - G.8262 Section 7.2

Hold-in range is defined as the largest offset between a slave clock's reference frequency and a specified nominal frequency within which the slave clock maintains lock as the frequency varies arbitrarily slowly over the frequency range.

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	Not Applicable		
EEC Option 2	EEC is locked to the clock from the Paragon-X. The frequency is then offset to ±4.6ppm	EEC should remain locked at an offset of ±4.6ppm	Lock may also be monitored by using ESMC

5.3 Pull–Out Range - G.8262 Section 7.3

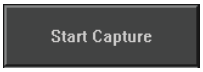
Pull-out range is defined as the offset between a slave clock's reference frequency and a specified nominal frequency within which the slave clock stays in the locked mode and outside of which the slave clock cannot maintain locked mode, irrespective of the rate of the frequency change.

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	EEC is locked to the clock from Paragon-X. The frequency is then offset until the EEC loses lock.	EEC should remain locked at an offset at ±4.6ppm but lock should extend beyond this.	Included for guidance only - G.8262 states this is for further study
EEC Option 2	Not Applicable		

5.4 Measurement Setup

a) Connect the EEC and Paragon-X as shown in **Error! Reference source not found.**
b) Ensure Paragon-X is configured as per Section 3 including enabling ESMC with SSM = QL-PRC (if using ESMC for monitoring)

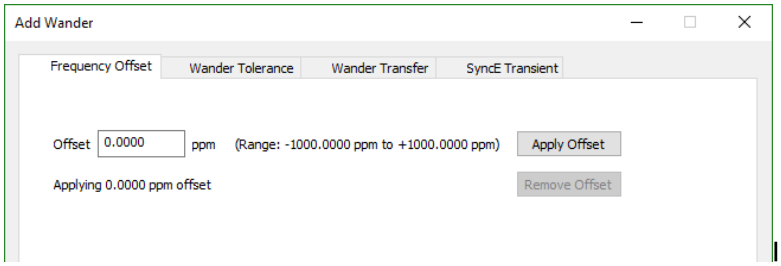
5.5 Measurement Process

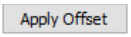
a) Select the 

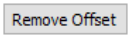
button to start the measurement

b) Select the 

button then select the ***Frequency Offset*** tab

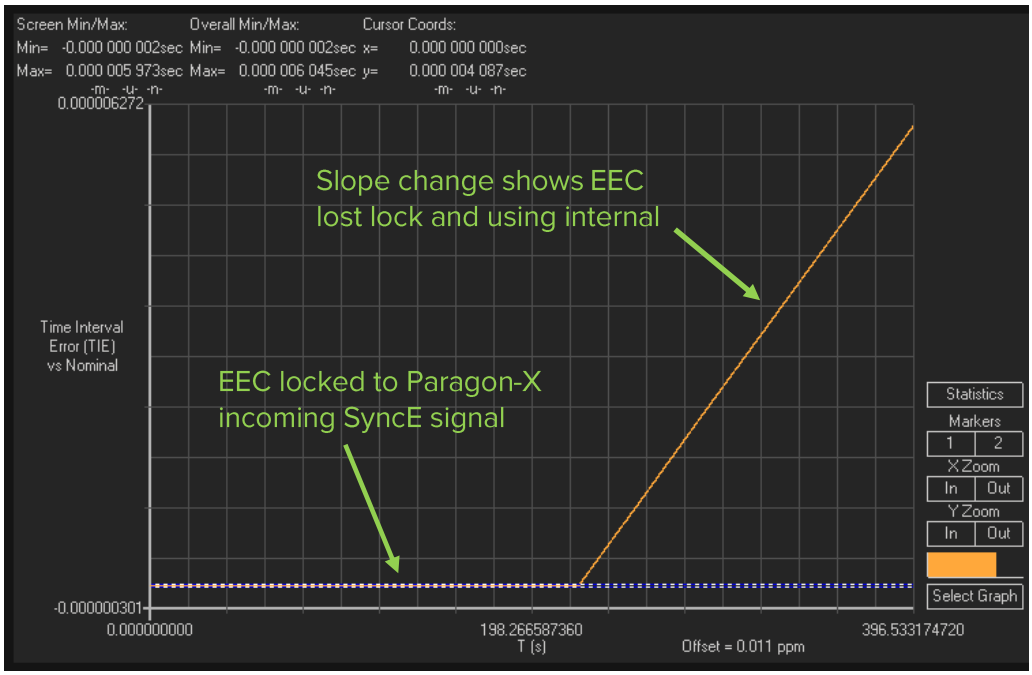


c) In the ***Frequency Offset*** tab, enter the offset required and click the 

button
d) When desired, remove the Frequency Offset (reset it to 0ppm) by clicking the 

button
e) To manually stop the measurement after the desired period, select the 

button
f) The Paragon-X TIE (Time Interval Error) graph indicates if the EEC is in or out of lock as shown in the screenshot below.



6 Wander (Noise) Generation – G.8262 Section 8

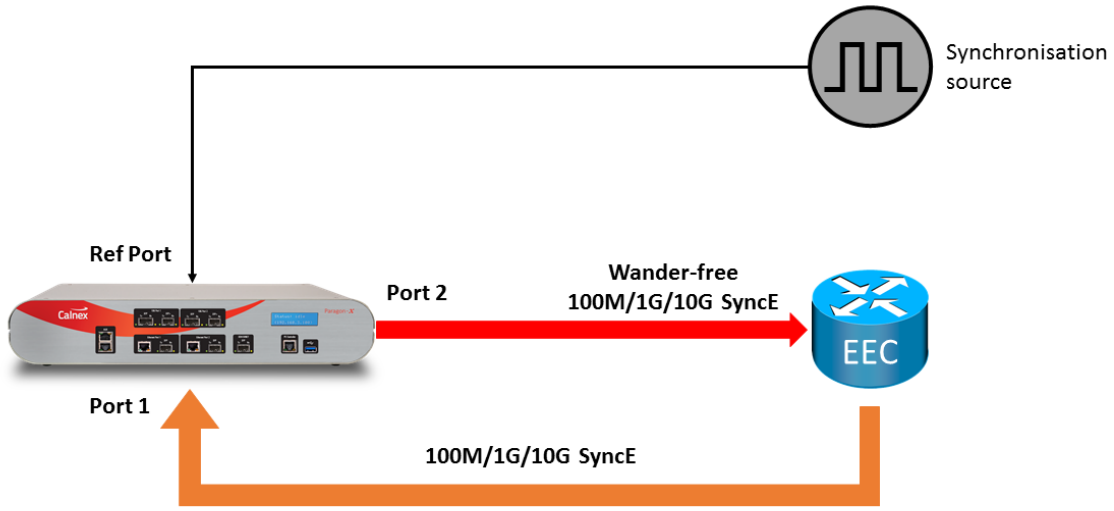


Figure 6: Wander generation test set-up

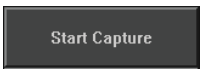
	Input Stimulus	Pass/Fail Criteria	Notes (G.8262 masks)
EEC Option 1 (Constant Temp)	Locked to wander-free reference Constant temperature	MTIE & TDEV Pass/Fail masks shown in G.8262 Section 8.1.1	MTIE – Table 1, Figure 1 TDEV – Table 3, Figure 2
EEC Option 1 (Temp effects)	Locked to wander-free reference Temperature effects	MTIE Pass/Fail masks shown in G.8262 Section 8.1.1	MTIE – Table 1&2, Figure 1 TDEV – "for further study"
EEC Option 2 (Constant Temp)	Locked to wander-free reference Constant temperature	MTIE & TDEV Pass/Fail masks shown in G.8262 Section 8.1.2	MTIE – Table 4, Figure 3 TDEV – Table 5, Figure 4

For EEC behavior in non-locked mode (as per G.8262 clauses 8.2 and 11.2) please see Section 11 of this document.

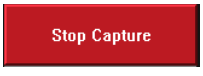
6.1 Measurement Setup

a) Connect the EEC and Paragon-X as shown in Figure 6.
b) Ensure Paragon-X is configured as per Section 3, including enabling ESMC with QL=PRC if using ESMC for monitoring.

6.2 Measurement Process

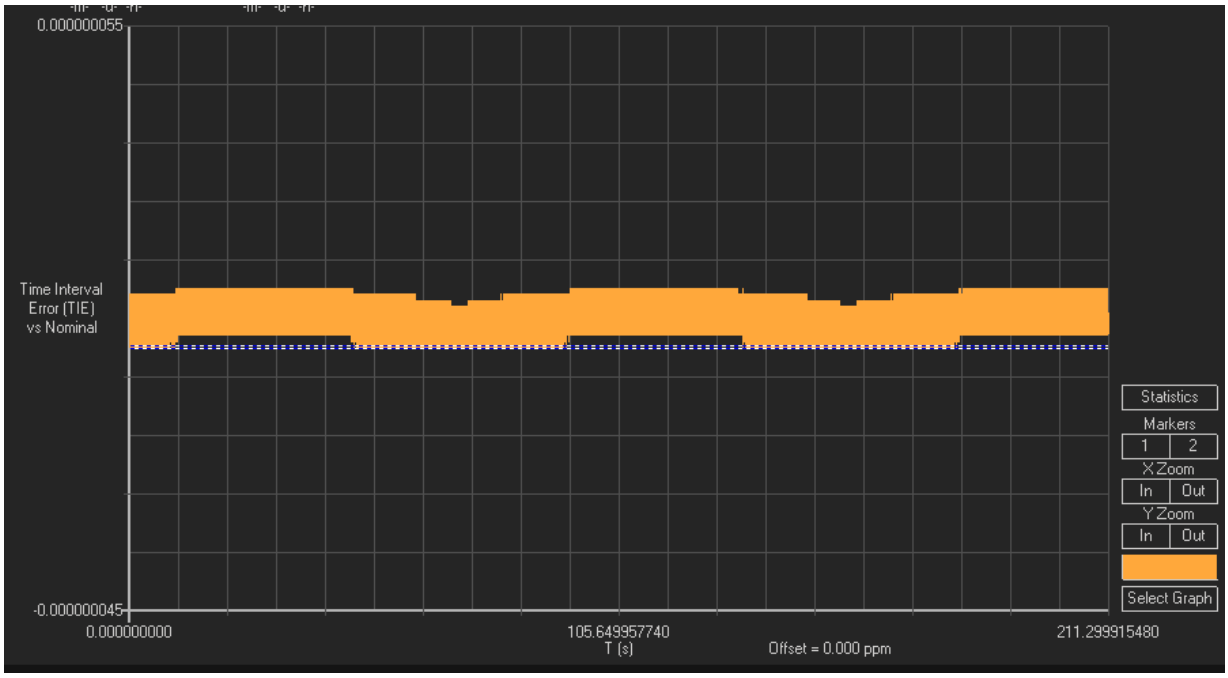
a) Select the 

button to start the measurement.

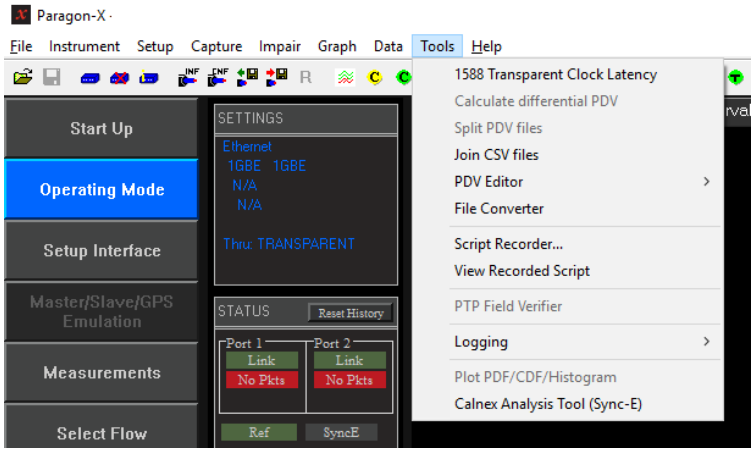
b) To stop the measurement, select the 

button. It is suggested that the test should run for approximately 50 minutes

c) The graph will show the captured `TIE`



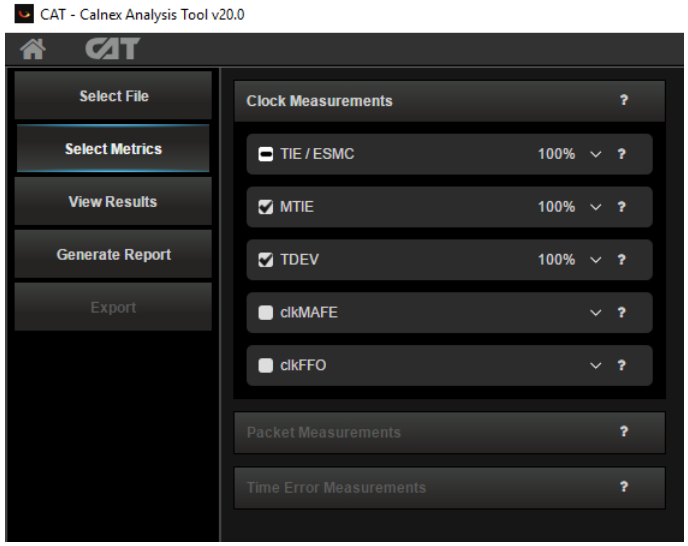
d) To display the `MTIE` and `TDEV` graphs launch the ***Calnex Analyzer Tool*** from the bottom of the ***Tools*** drop-down menu



e) A separate window will open showing the `TIE` in graphical form.

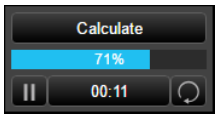
f) The x-axis zoom level of the graph can be controlled by using the icons to the right of the graph area.

g) Enable the `MTIE` and `TDEV` metrics by using the **Select Metrics** button then selecting the desired metrics from the displayed list.

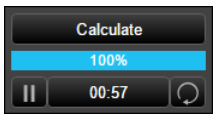


h) After selection, click the ***Calculate*** button to perform the selected analyses:

The ***Calculate*** button causes the metrics to be recalculated. The progress of the calculation progress is shown on the progress bar:

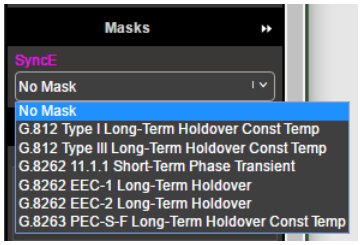


After calculating, the results indicator will show 100%:



The analysis will be automatically refreshed every 60s as shown in the countdown timer below the progress indicator bar.

i) The results can be reviewed against the standards-defined G.8262 masks by choosing from the mask selection dropdown menu to the right of each graph:



j) A Pass or Fail indication against the selected mask is shown in the top right corner of the CAT window

7 Jitter Generation – G.8262 Section 8.3

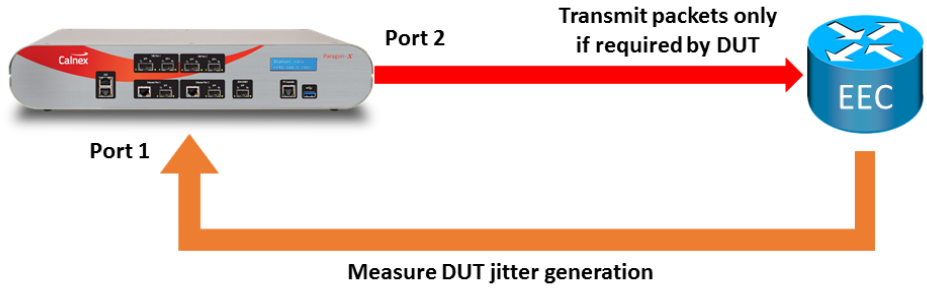


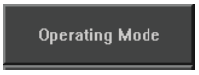
Figure 7: Jitter Generation Test Set-Up

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1 and EEC Option 2	None, unless DUT requires packet stream to function	Output jitter <=0.5UIpp in 60-second window, as G.8262 8.3 Table 6	• Measurement filter bandwidths specified in G.8262 Table 6 • G.8262 treats 1G electrical as "for further study". Calnex recommends using the same 0.5UIpp limit until further defined by ITU.

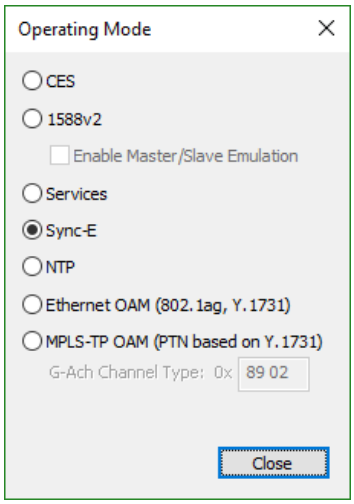
7.1 Measurement Setup

a) Connect the EEC and Paragon-X as shown in Figure 7.
b) Ensure Paragon-X is configured as per Section 3.

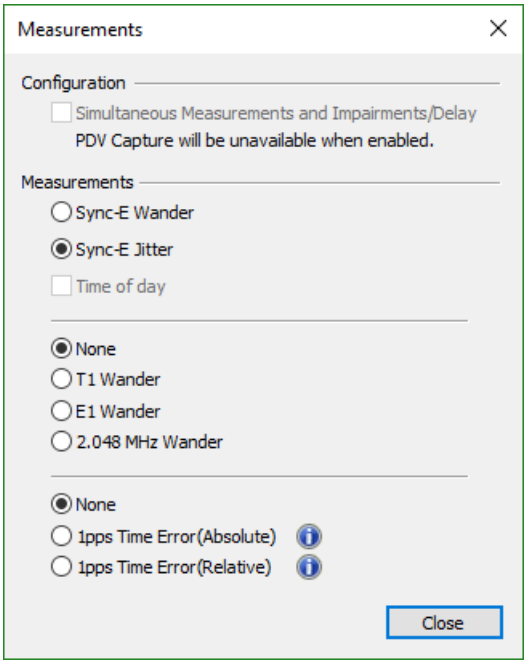
7.2 Measurement Process

a) Select the 

button and select ***Sync-E*** followed by ***Close***

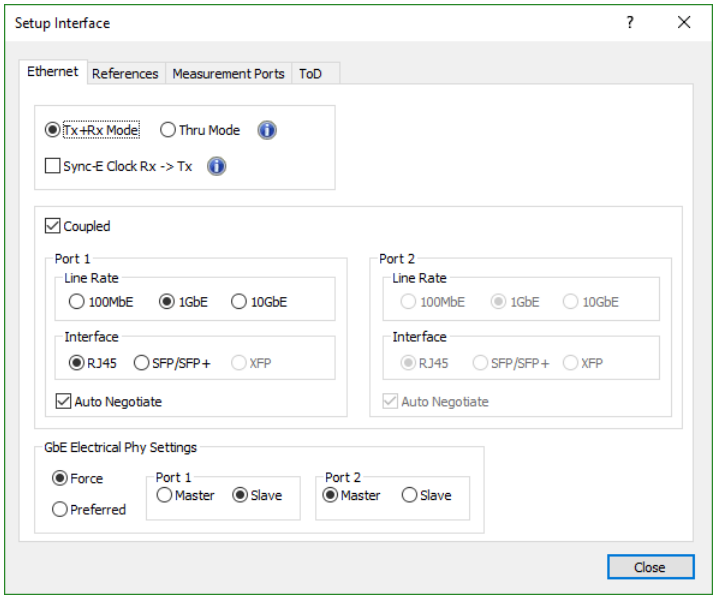


b) Select the Measurements button and select ***Sync-E Jitter*** followed by ***Close***



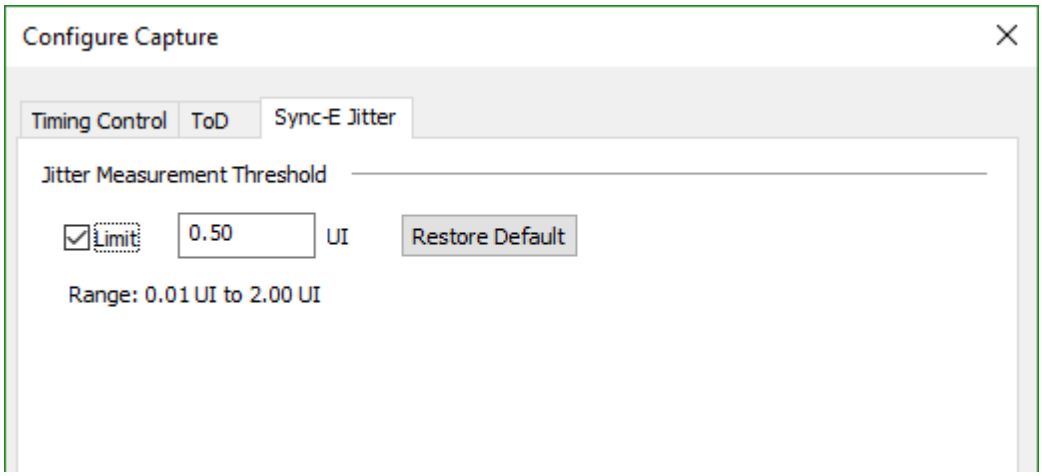
NOTE: Interface rate choice will automatically be restricted to 1GbE and 10GbE - 100MbE is not available in jitter measurement mode. For 10Gbit/s optical, device type is restricted to SFP/SFP+ - XFP is not available.

Normally, the operating configuration is set to ***Tx+Rx Mode***.

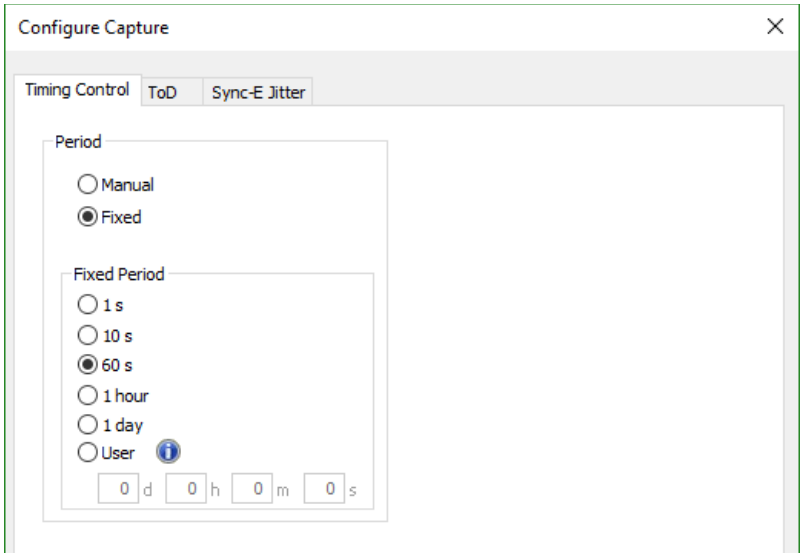


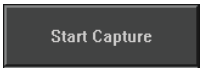
c) Selecting Configure Capture then the ***SyncE-Jitter*** tab will display the window shown below which allows the ***Jitter Measurement Threshold*** setting to be configured. If the checkbox is ticked, the capture (result) screen will indicate a pass or fail for the peak-peak jitter result currently

selected. Note that the threshold result is compared to the instantaneous graph result and so its behaviour is different between long-term and short-term peak-to-peak graph selections.



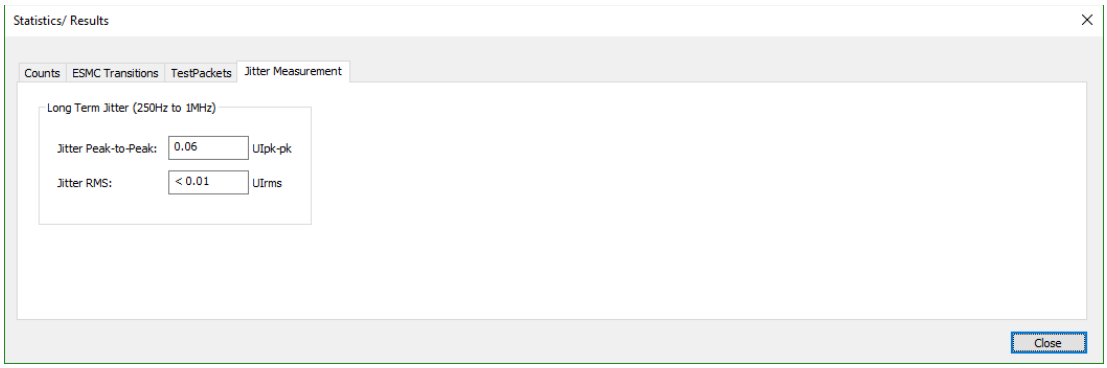
d) G.8262 specifies a pk-pk jitter measurement time of 60s. Selecting ***SyncE Jitter*** as above configures the capture ***Timing Control*** to a fixed 60s measurement, which overrides the ***manual*** global default capture configuration in Paragon-X. Select other periods or ***Manual*** if required for experimentation or observing long-term device behaviour, but note that a period of 60s must used when making a G.8262 compliance measurement.



e) Initiate jitter measurement using the 

button. This will display the ***Jitter Measurement*** tab of the ***Statistics/Results*** window. This tab shows long-term (i.e. over the total elapsed time) pk-pk and RMS jitter results. It also shows the measurement bandwidth, which is fixed depending on interface type selected. Limit checking is not applied to the jitter measurement tab. The tab can be closed and re-opened any time via the 

button.

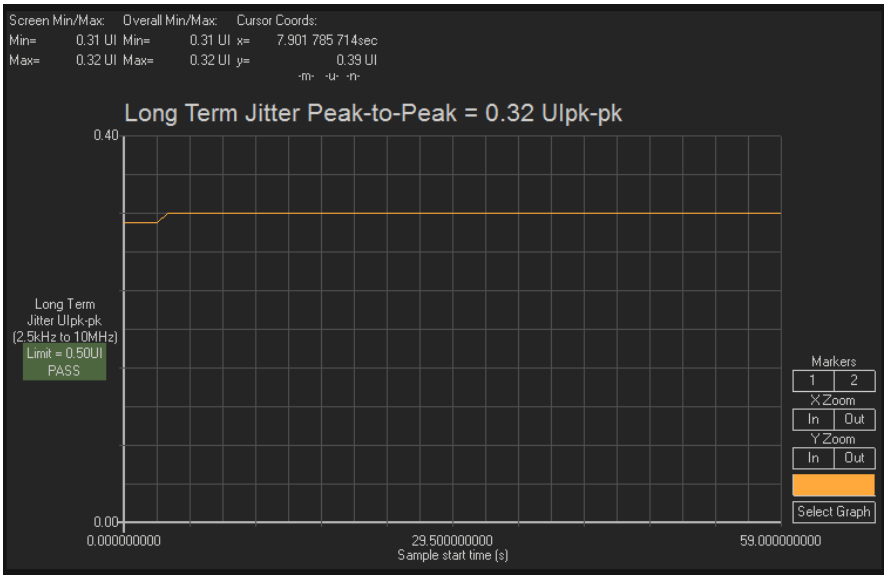


f) The main capture screen is updated once per second with measurements for long-term jitter UIpk-pk, long-term jitter RMS, and short-term (one second) pk-pk jitter.

Use the Select Graph button in the bottom-right of the main screen to select a result for graphing. The measurement bandwidth is also displayed alongside the Y-axis legend on the graph.

Note that sample periods (1-second intervals) are numbered based on the start time of each one-second period (i.e. starting from 0), so a 60-second total measuring period will show as containing sample periods 0-59.

A Pass/Fail result will be shown for the 60s long-term peak-to-peak value compared to the G.8262 0.5UI limit:



8 Wander (Noise) Tolerance – G.8262 Section 9

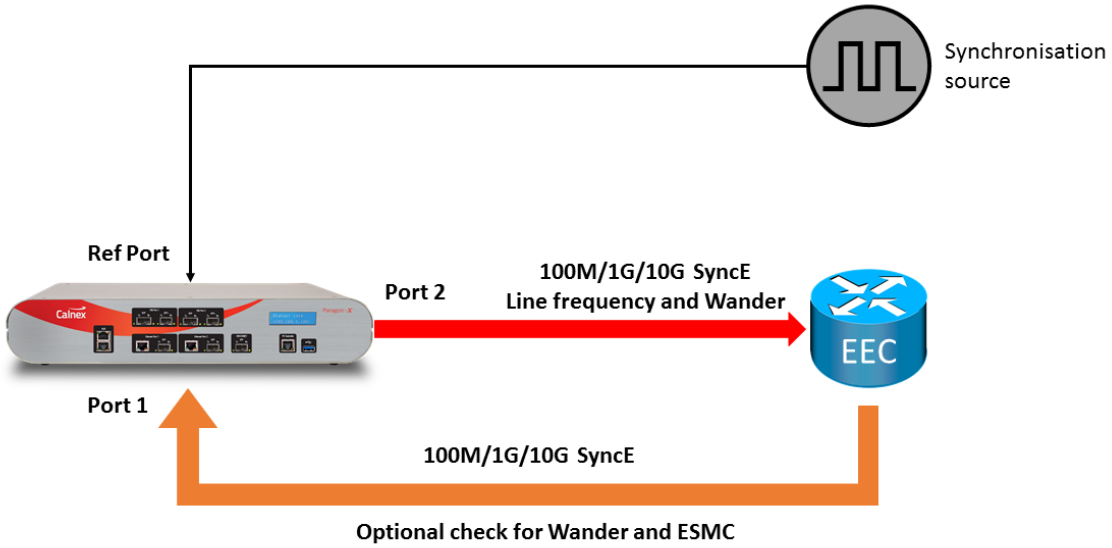


Figure 8: Wander Tolerance Test Set-Up

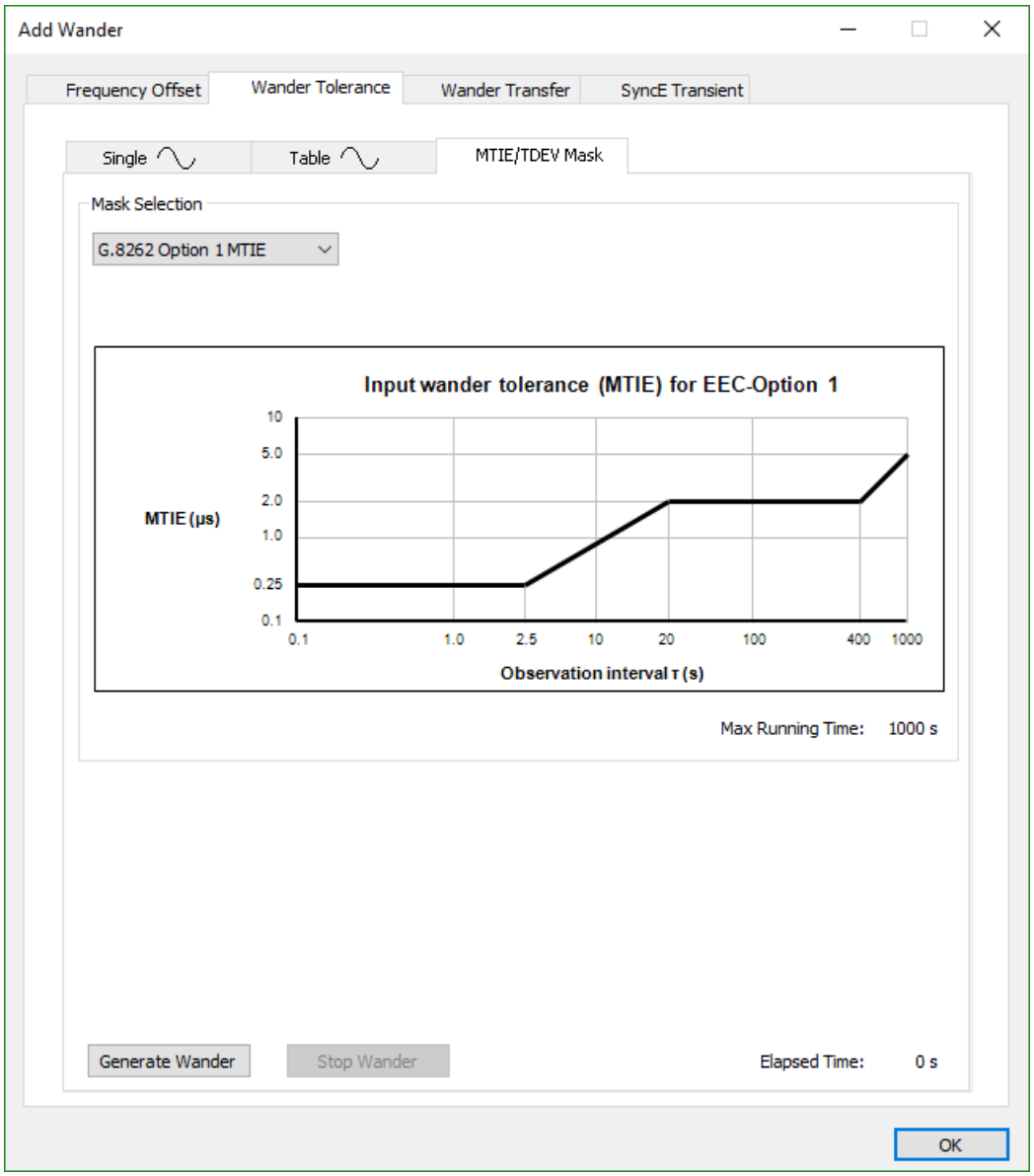
	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	• MTIE Wander Table 7/Figure 5 • TDEV Wander Table 8/Figure 6 • Sinusoidal Wander Table 9/Figure 7	The EEC should • Maintain the clock within performance limits; • Not cause any alarms; • Not cause the clock to switch reference; • Not cause the clock to go into holdover.	Paragon-X can measure the wander and/or ESMC QL of the EEC output to indicate whether the EEC is switching references or going into holdover.
EEC Option 2	• TDEV Wander Table 10/Figure 8	The EEC should • Maintain the clock within performance limits; • Not cause any alarms; • Not cause the clock to switch reference; • Not cause the clock to go into holdover.	Paragon-X can measure the wander and/or ESMC QL of the EEC output to indicate whether the EEC is switching references or going into holdover.

8.1 Measurement Setup

a) Connect the EEC and Paragon-X as shown in Figure 8.
b) Ensure Paragon-X is configured as per Section 3, including enabling ESMC with QL=PRC if using ESMC for monitoring.

8.2 Measurement Process

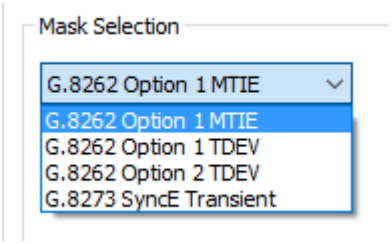
a) Select the Add Wander button on Paragon-*X* GUI and ensure the ***Wander Tolerance*** tab is selected



b) Paragon-X can generate three types of wander:
   i. `MTIE/TDEV` Wander: the fastest and most effective way to evaluate an EEC
   ii. Table Sinusoidal Wander: can be used for finding Maximum Tolerable Wander
   iii. Single Sinusoidal Wander: can be used for troubleshooting

8.2.1 MTIE/TDEV Wander

Paragon-X can generate `MTIE` and `TDEV` wander as defined in G.8262.



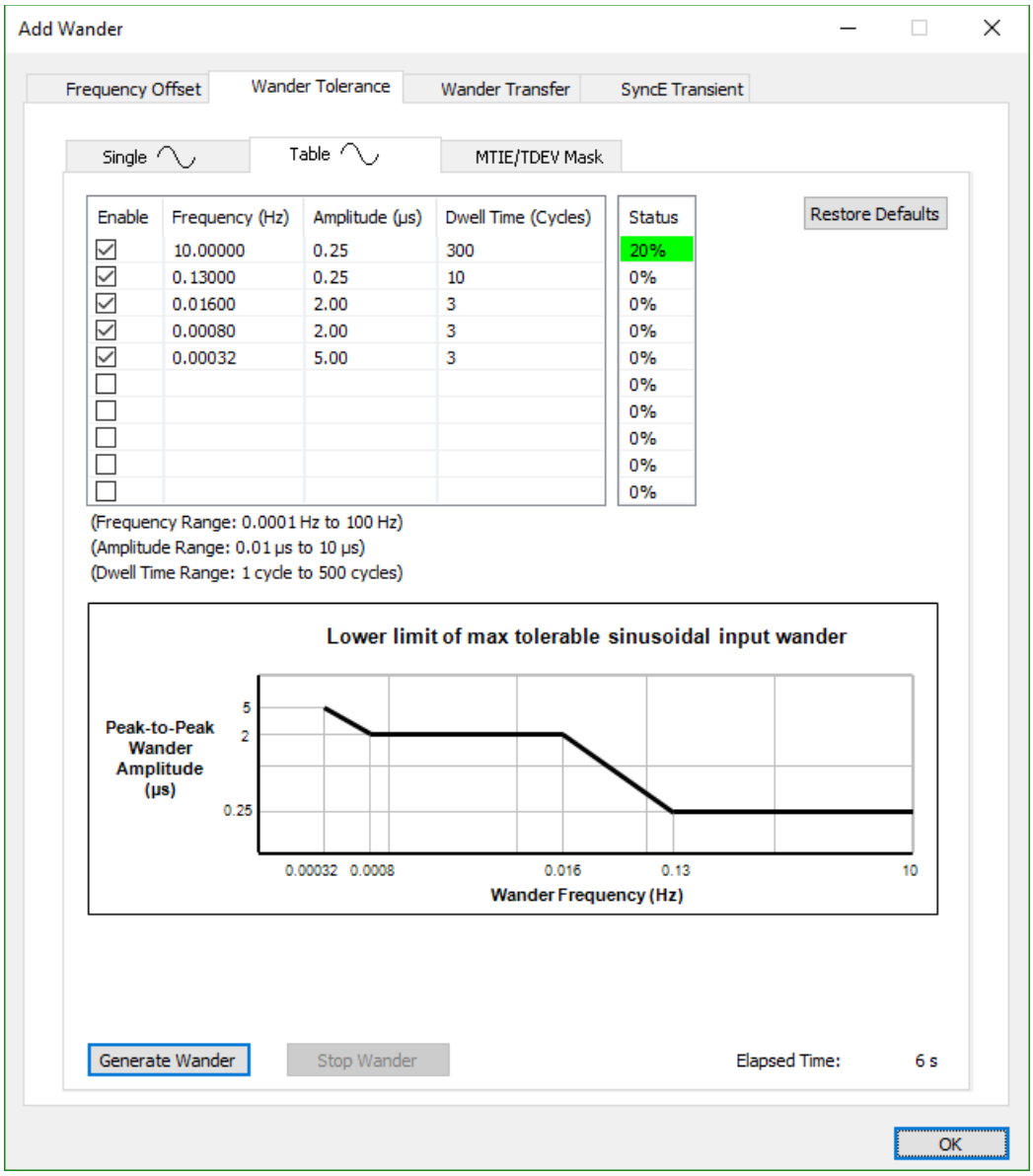
a) Select the wander profile required from the drop-down list. The profile and the maximum running time will be shown below the selection.
   - G.8262 Option 1 `MTIE` Run time is 1000s
   - G.8262 Option 1 `TDEV` Run time is 12000s
   - G.8262 Option 2 `TDEV` Run time is 12000s
   - (G.8273 SyncE Transient Run time is 200s – not relevant for this G.8262 test procedure)

b) Click Generate Wander to start the test. The elapsed time will be displayed on the bottom right corner of the window.

c) The test will stop after the max running time has elapsed, but can also be stopped manually by clicking Stop Wander

8.2.2 Table ∿

To generate sinusoidal wander, the user can enter up to 10 different wander parameter sets in the table. Paragon-X will generate each of the specified wander sets in sequence and show progress in the ***Status*** column. Switching between different sets always occurs at a zero crossing to prevent phase steps.



a) Enter the frequency, amplitude, and dwell time (number of cycles the frequency/amplitude pair will be run) for each wander test point. Note:

- the same frequency with different amplitudes can be entered to find maximum tolerable wander
- the Restore Defaults button can be used to reset the values to those defined in G.8262 Table 9.
- only rows that have the ***Enable*** checkbox ticked will be executed in the test. To skip a selection, un-tick the ***Enable*** box for that row.

The pre-populated default values may be used to determine DUT performance. For enhanced measurement a more comprehensive set of test frequencies may be used. An explanation for the values in the tables below may be found in **SyncE Wander Tolerance using Tones: EEC Option 1** and **SyncE Wander Tolerance using Tones: EEC Option 2**.

The frequency, amplitude and dwell time values may be entered into the Table shown above. The **Test Time** column in the tables below is included for convenience when planning testing. When suitable values have been input ensure the checkbox is ticked for each row to be executed.

EEC Option 1:

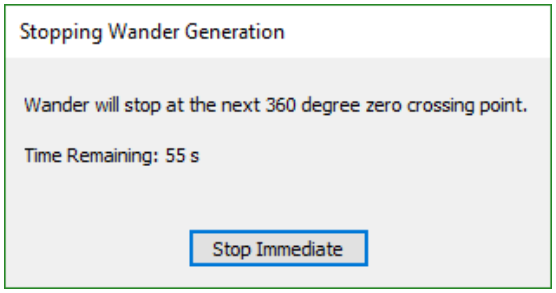
Frequency (Hz)	Amplitude (ns)	Dwell Time (Cycles)	Test Time (s)
10	250	1500	150
1	250	150	150
0.13	250	20	154
0.016	2000	4	250
0.0032	2000	4	1250
0.0008	2000	3	3750
0.00032	5000	3	9375

EEC Option 2:

Frequency (Hz)	Amplitude (ns)	Dwell Time (Cycles)	Test Time (s)
3.2	300	480	150
0.32	303	150	150
0.032	325	8	250
0.0032	550	4	1250
0.0011	1000	3	2727
0.00032	1007	3	9375

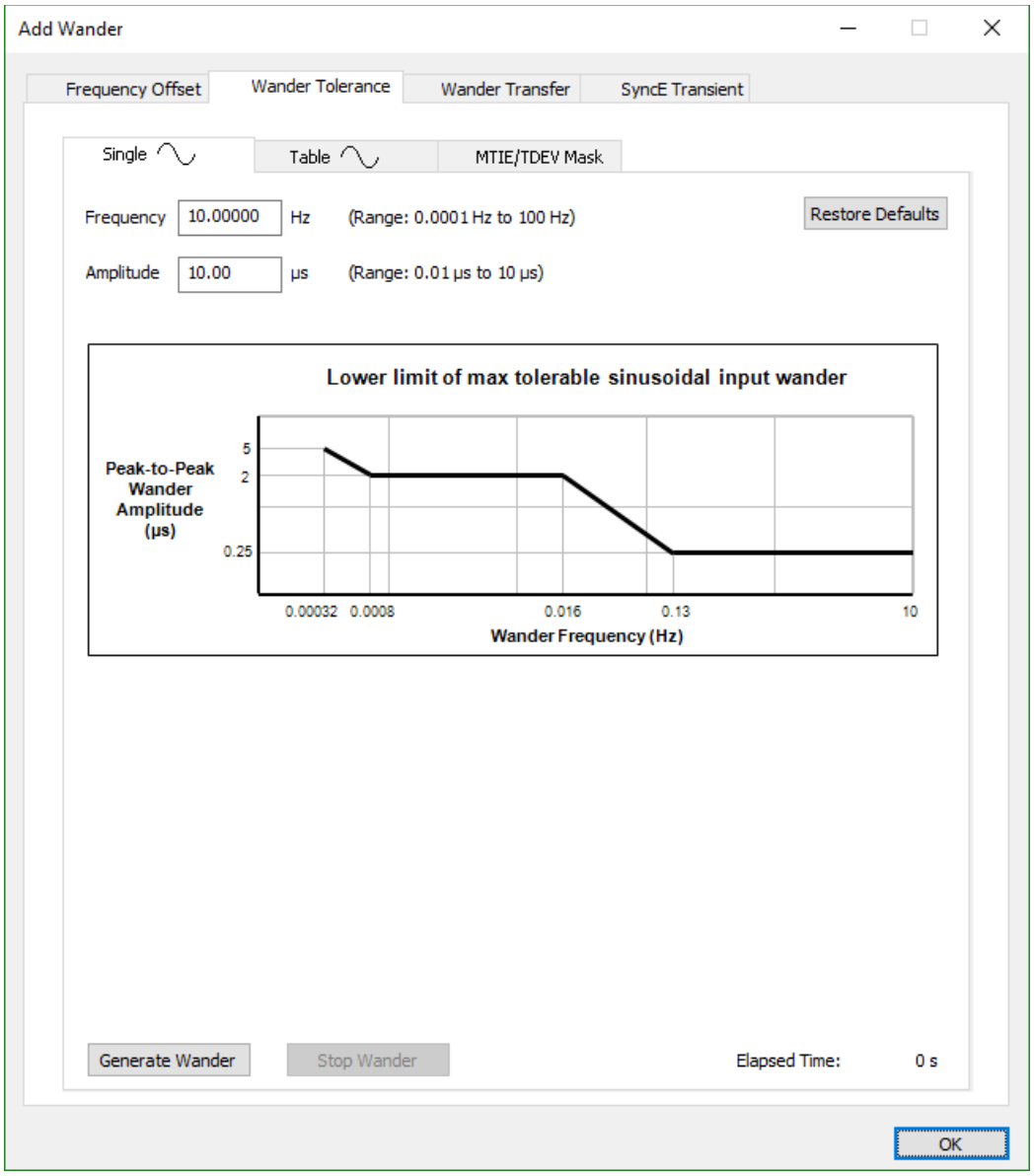
b) Click Generate Wander to start the test

c) Click Stop Wander to stop the test at the next zero crossing. A pop-up box indicating how long until the next zero crossing is displayed. Click the ***Stop Immediate*** button if it is desired to do so.



8.2.3 Single ∿

Can be used for troubleshooting issues at a specific frequency.



a) Enter the frequency and amplitude of the desired wander

b) Click Generate Wander to start the test

c) Click Stop Wander to request to stop the test at the next zero crossing. A pop-up box indicating how long to the next zero crossing is displayed. Click the ***Stop Immediate*** button if it is desired to do so.

8.2.4 Investigating Issues

G.8262 states that with wander applied the EEC should:

- maintain the clock within the prescribed performance limits (the exact performance limits are for further study)
- not cause any alarms

- not cause the clock to switch references
- not cause the clock to go into holdover

Paragon-X ESMC generation/capture and the TIE data can be used to check whether the EEC is switching clock reference or going into holdover.

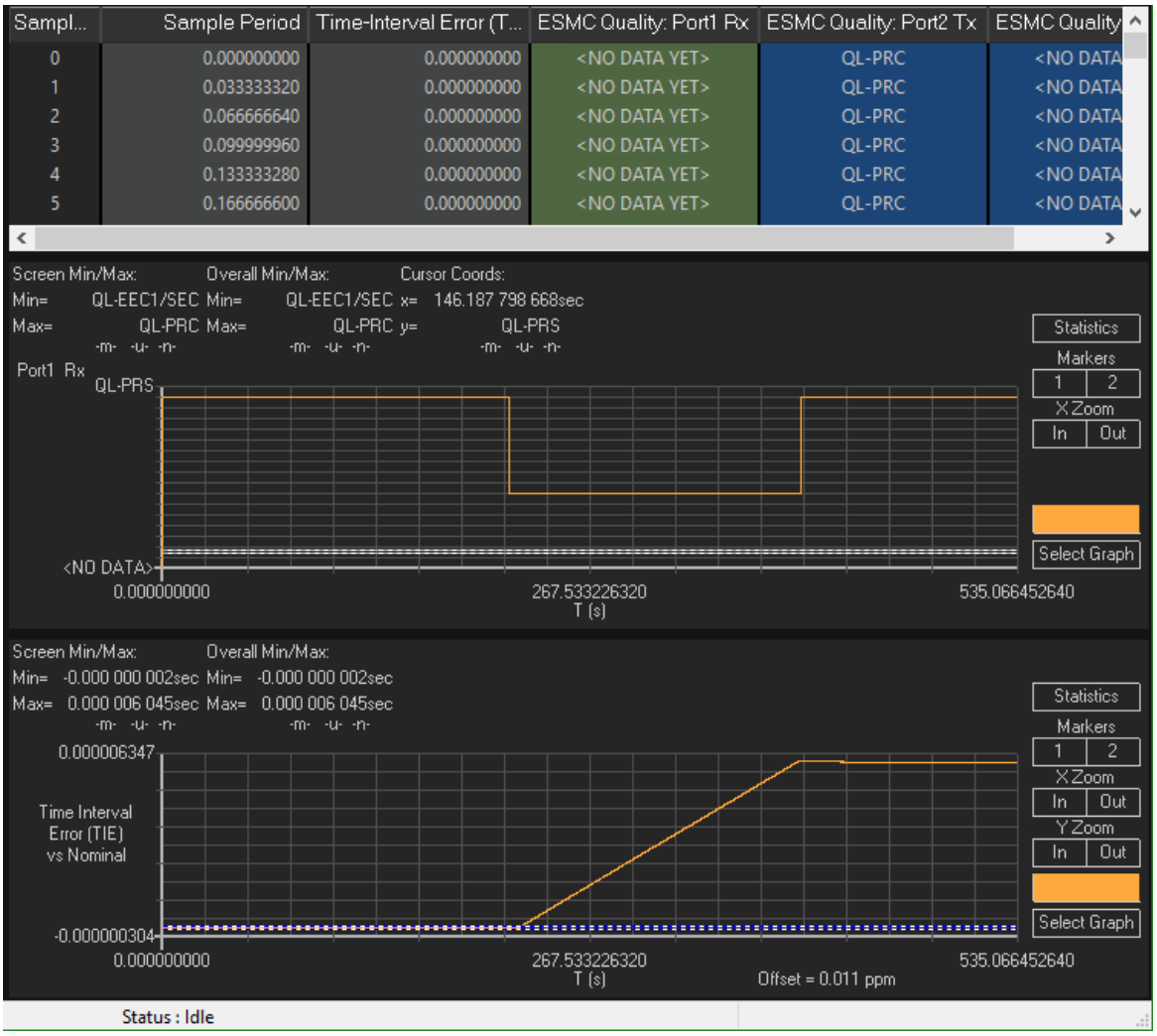
a) Ensure the Paragon-*X* is generating ESMC messages with QL=PRC as described in Section 3 of this document.

b) Select the Start Capture button to start the measurement.

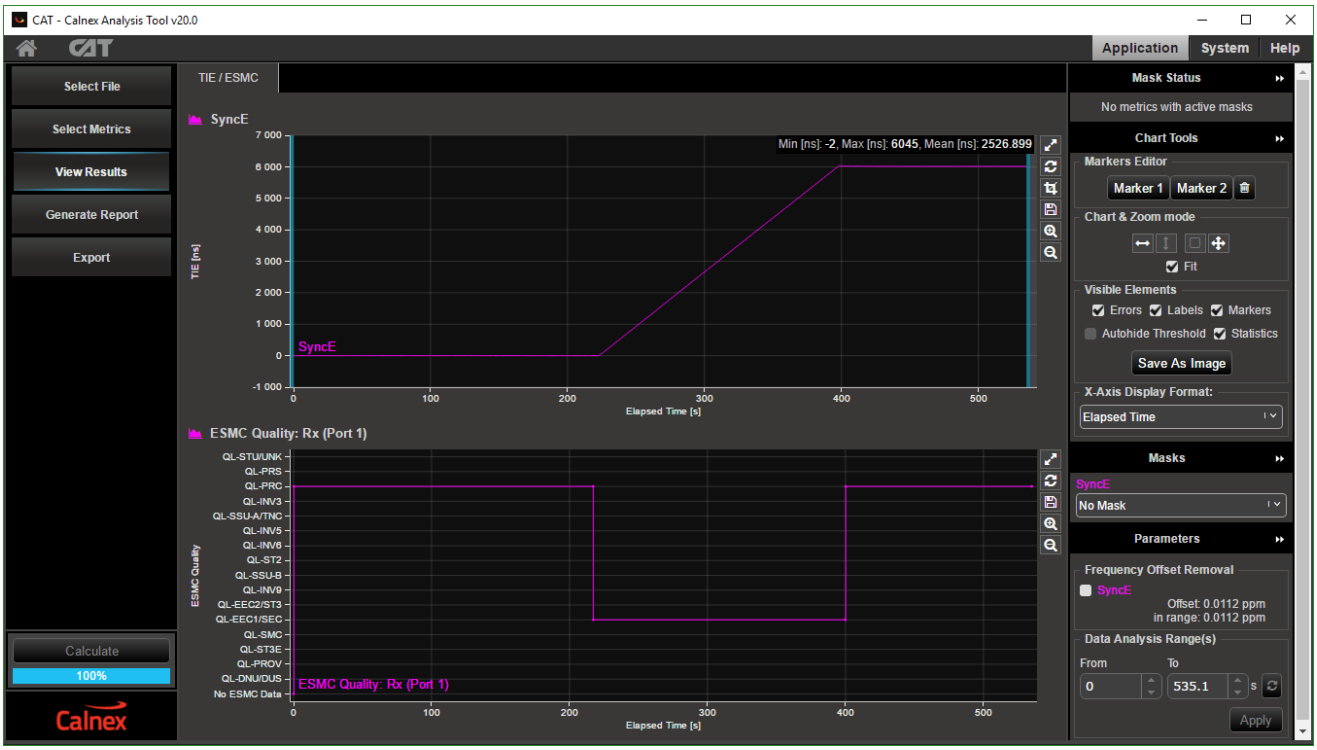
c) To show both the TIE and ESMC graph at the same time click Select Graph then ***Show 2nd Graph*** and select ***ON***

To configure what data is displayed in a graph click Select Graph then ***Graph Display Mode*** then select the data to graph:

- Time Interval Error (TIE) vs Nominal
- ESMC Rx Quality vs Time: (Port 1 Rx)



The capture data can also be loaded into CAT for further analysis:



The Paragon-X GUI and CAT screenshots above show an EEC that has switched references or gone into holdover and then recovered.

e) To stop the measurement, select the 

button.

9 Jitter Tolerance – G.8262 Section 9.2

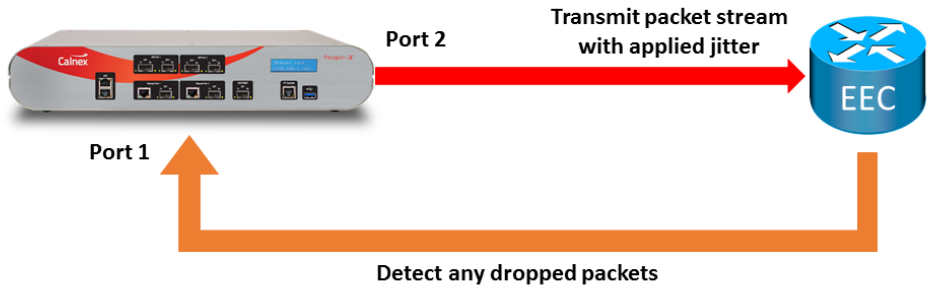
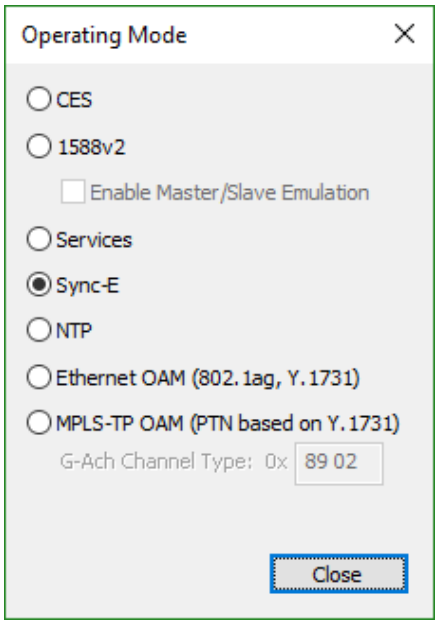


Figure 9: Jitter Tolerance Test Set-Up

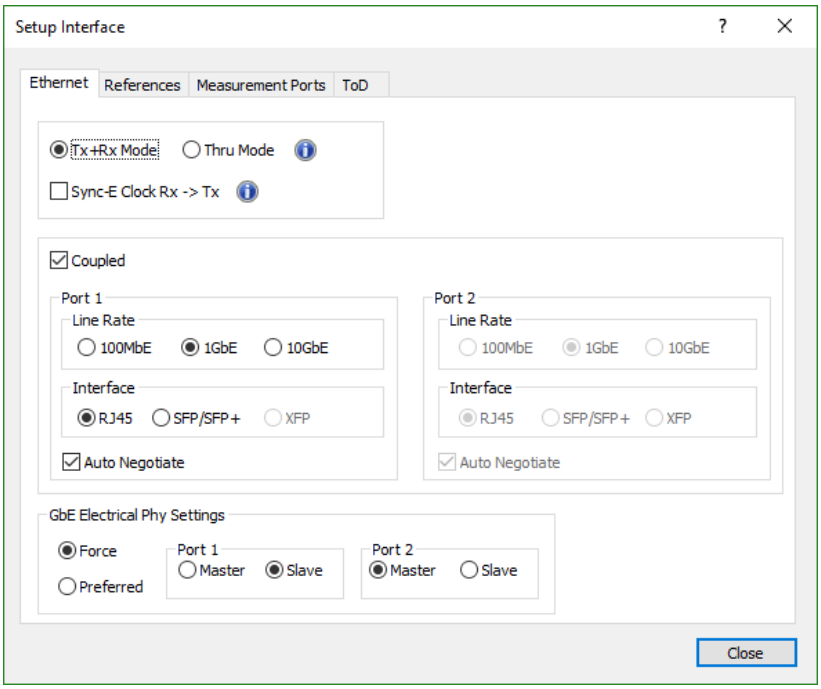
	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1 and EEC Option 2	• Packet stream from Paragon-X or thru-mode traffic • Superimpose jitter as per G.8262 Table 11 or 12 depending on speed selected (1G or 10G)	For all jitter values presented: • EEC does not drop packets • EEC does not error or alarm • EEC does not go into Holdover	• Allow settling time at each measurement point • Either as pass/fail with presented jitter values at the mask, or a margin test with jitter values above mask

9.1 Measurement Setup

a) Open the ***Operating Mode*** dialogue and select ***Sync-E*** operating mode.



b) Open ***Setup Interface*** dialogue

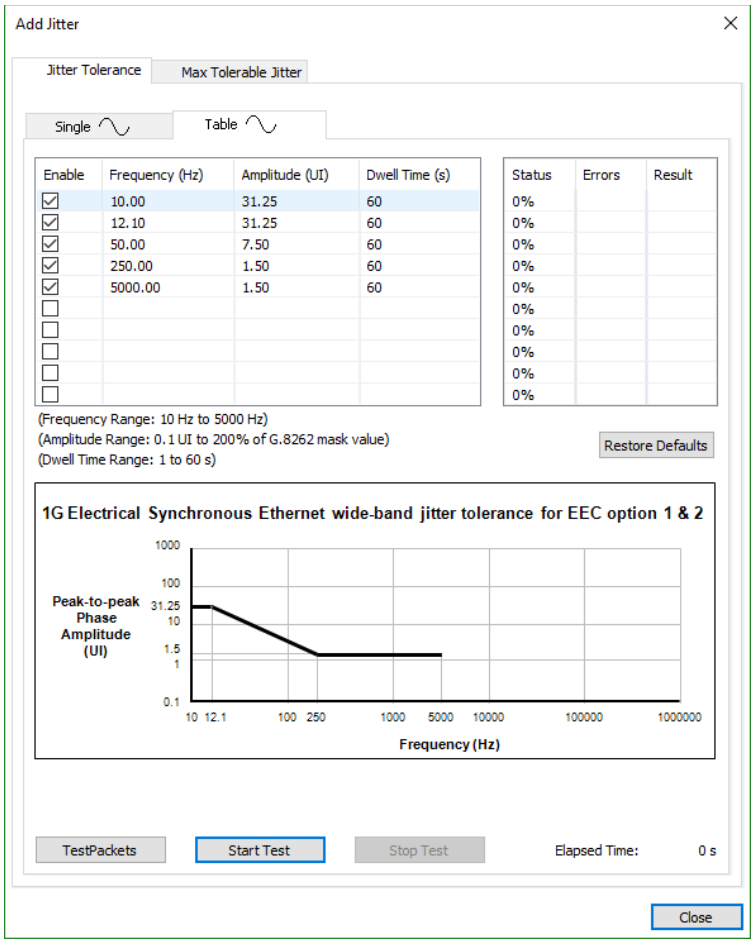


c) Select ***Tx+Rx Mode***

d) Select ***1GbE*** or ***10GbE*** Line Rate as appropriate.

e) Select the 

button then the ***Table*** ∿ tab

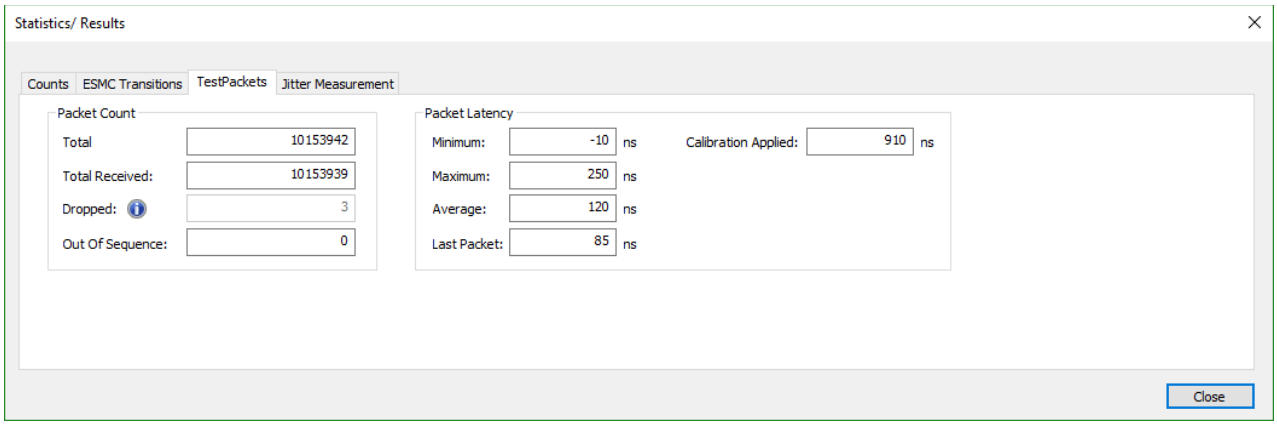


f) Selecting the TestPackets button will show the Test Packet Generation dialogue which allows configuration of the test packets to be generated. These settings may be left at default values or modified as required. Once suitable values are configured, click **Close** to return to the previous screen.

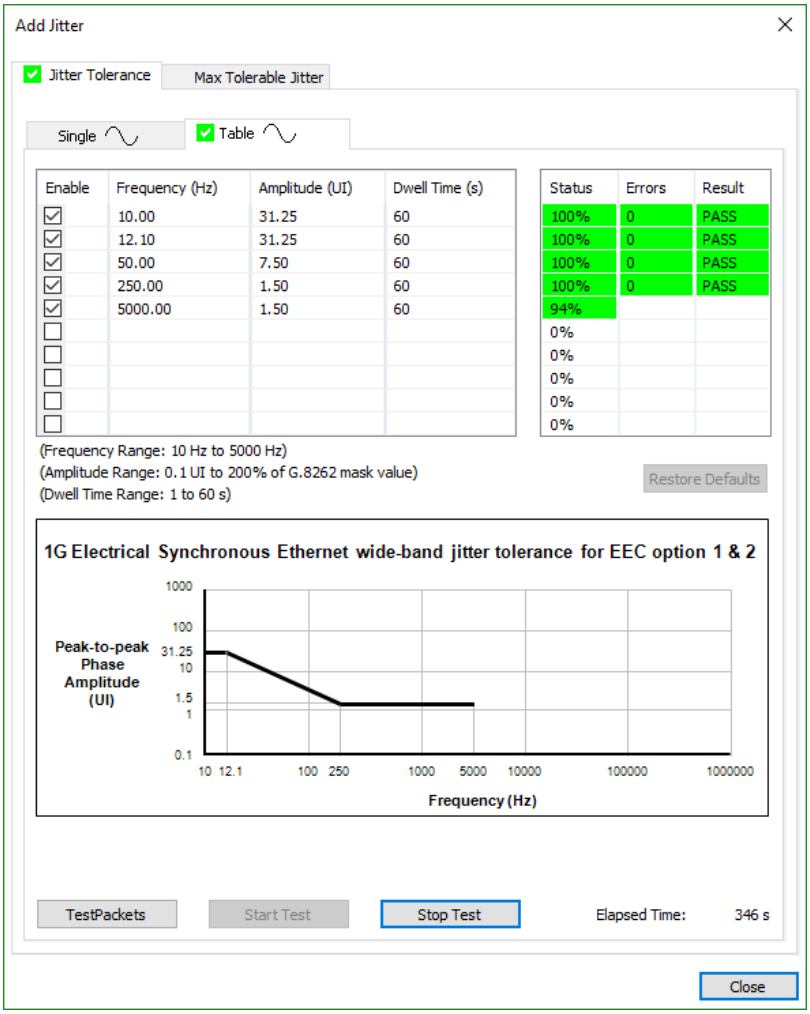
g) In the ***Jitter Tolerance Table*** tab enter the frequency, amplitude, and dwell time for the required measurements in each row.

h) Select the Start Test button. Test Packet generation will be automatically controlled as each row in the Jitter table is executed and the test will stop after all the enabled table rows have been executed.

i) Clicking the Statistics/ Results button then the **TestPackets** tab will display periodically-updated packet statistics while the test is running:

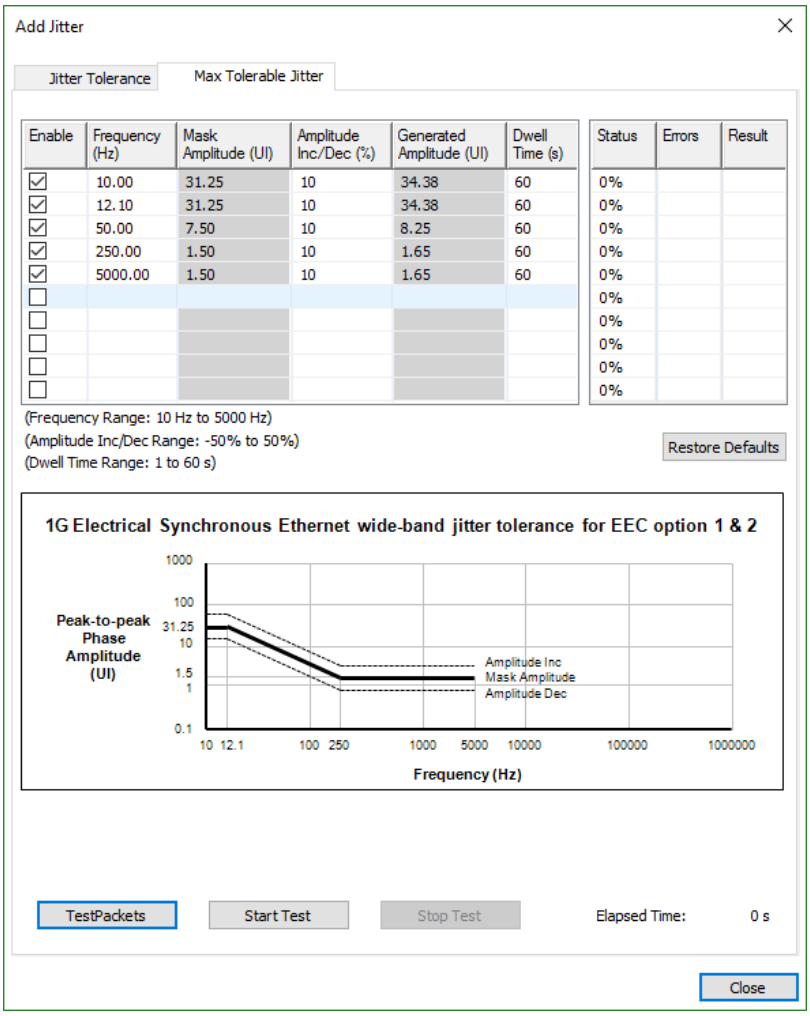


j) A ***PASS*** or ***FAIL*** for each row executed will appear in the ***Jitter Tolerance Table*** tab of the ***Add Jitter*** window. The result indicates whether any dropped packets were detected during the test.



The above test verifies that the EEC does not drop packets for all jitter values selected. However, it is important to also verify that the EEC does not Error/Alarm or go into Holdover during the test.

In the Max Tolerable Jitter mode, the operation is the same but with a configurable percentage change applied to the generated jitter amplitudes.



10 Wander (Noise) Transfer – G.8262 Section 10

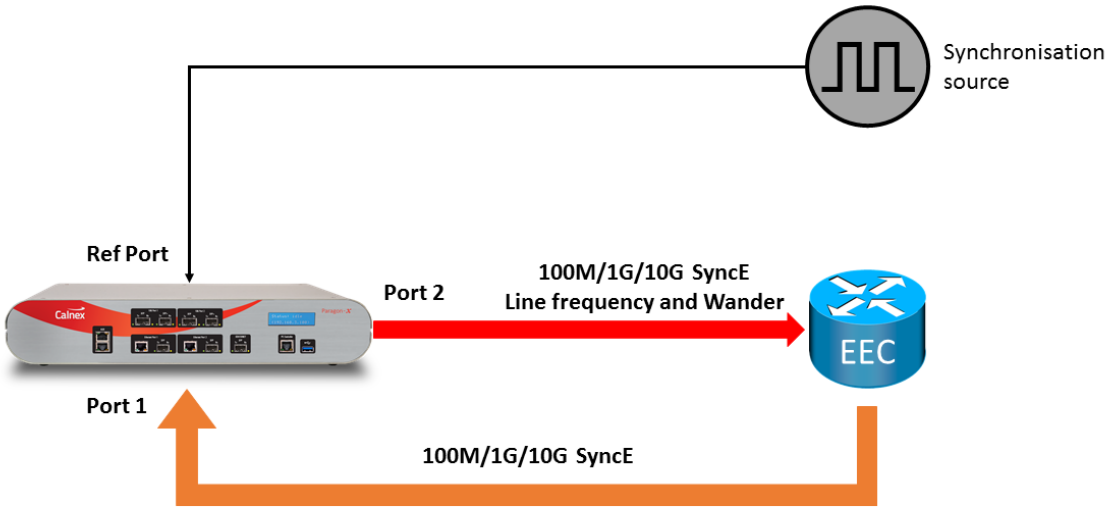


Figure 10: Wander Transfer Test Set-Up

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	Not defined by ITU-T.	A phase gain mask for the EEC low pass filter performance is shown below	Tests EEC in-band and out-of-band performance based on G.8262 by using a series of tones is described below.
EEC Option 2	TDEV Wander Table 10/Figure 8	Measure EEC output against TDEV Pass/Fail masks shown in G.8262 Section 10.2 Table 13/Figure 11	

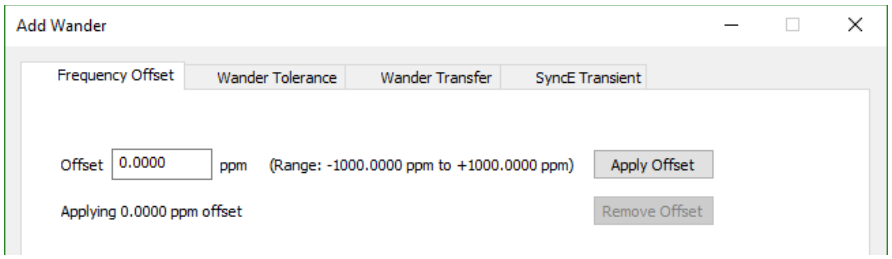
10.1 Measurement Setup

a) Connect the EEC to Paragon-*X* as shown in the diagram above.
b) Set up Paragon-X as described in section 3, including setting up ESMC with QL=PRC if using ESMC to monitor to which clock the EEC is locked.

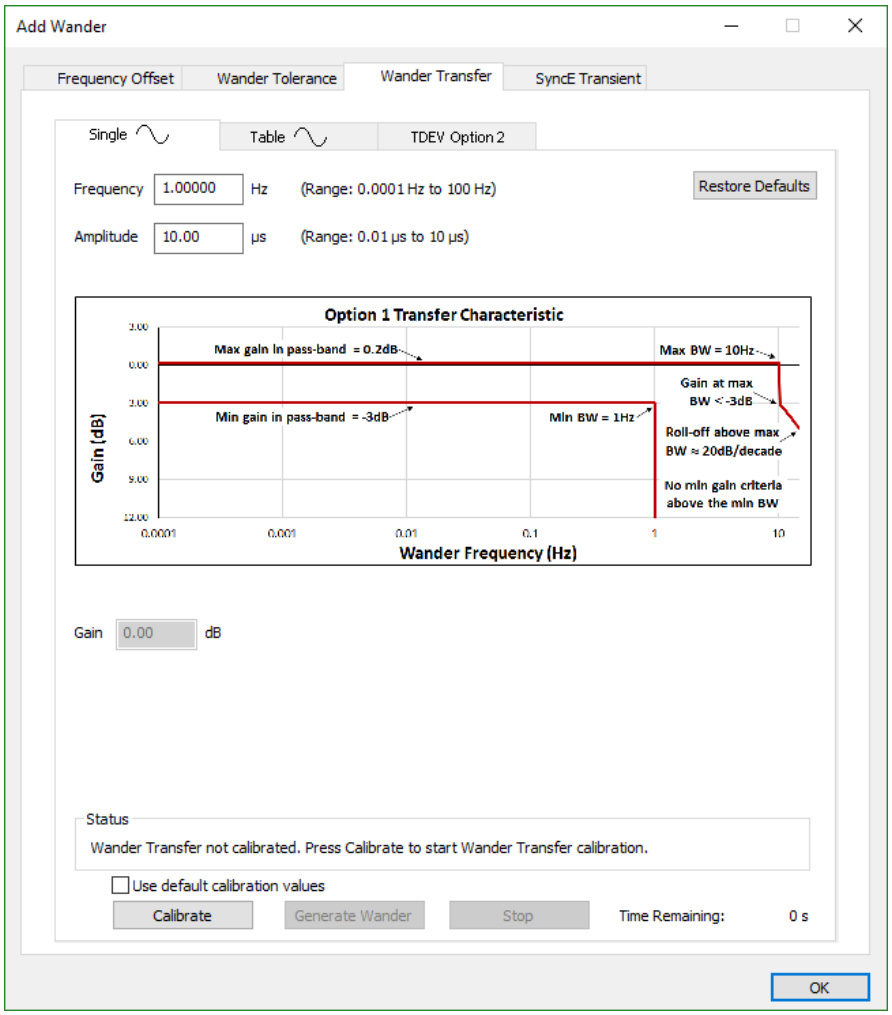
10.2 Measurement Process

a) Select the 

button to open the Wander configuration window:

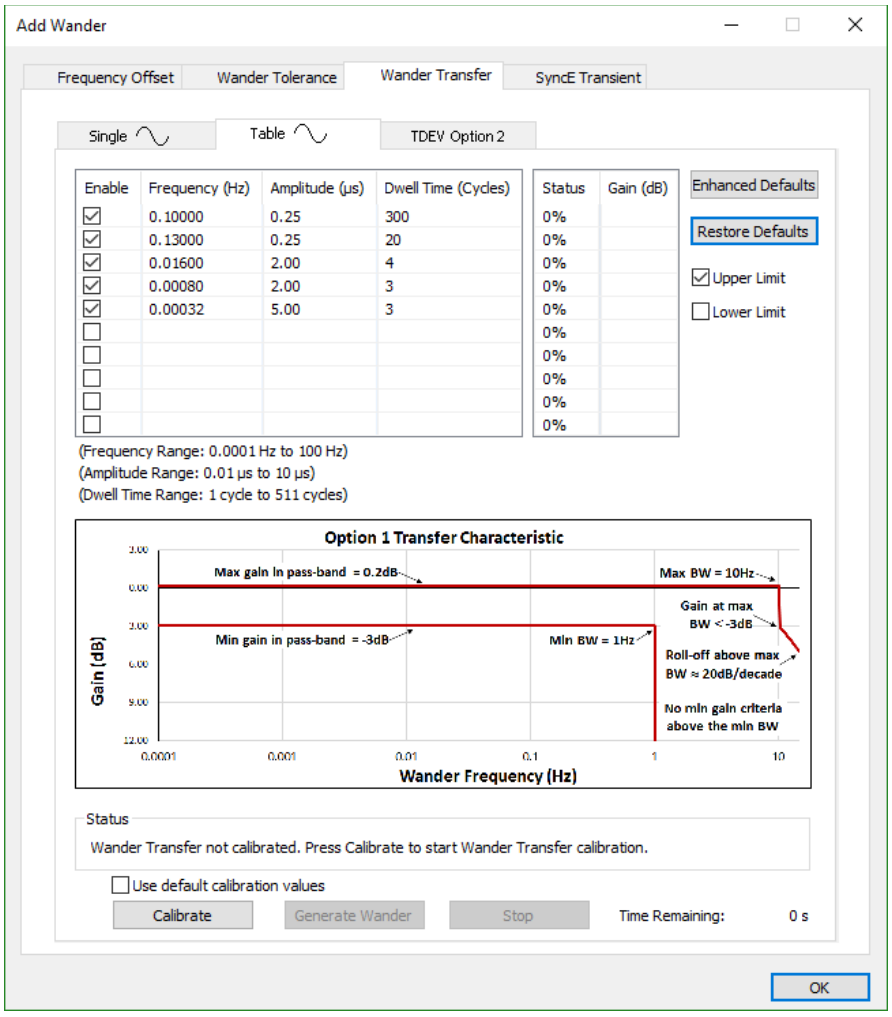


b) Select the ***Wander Transfer*** Tab to display the window shown below:



10.2.1 G.8262 Option 1 Wander Transfer Test: Paragon-X automated testing

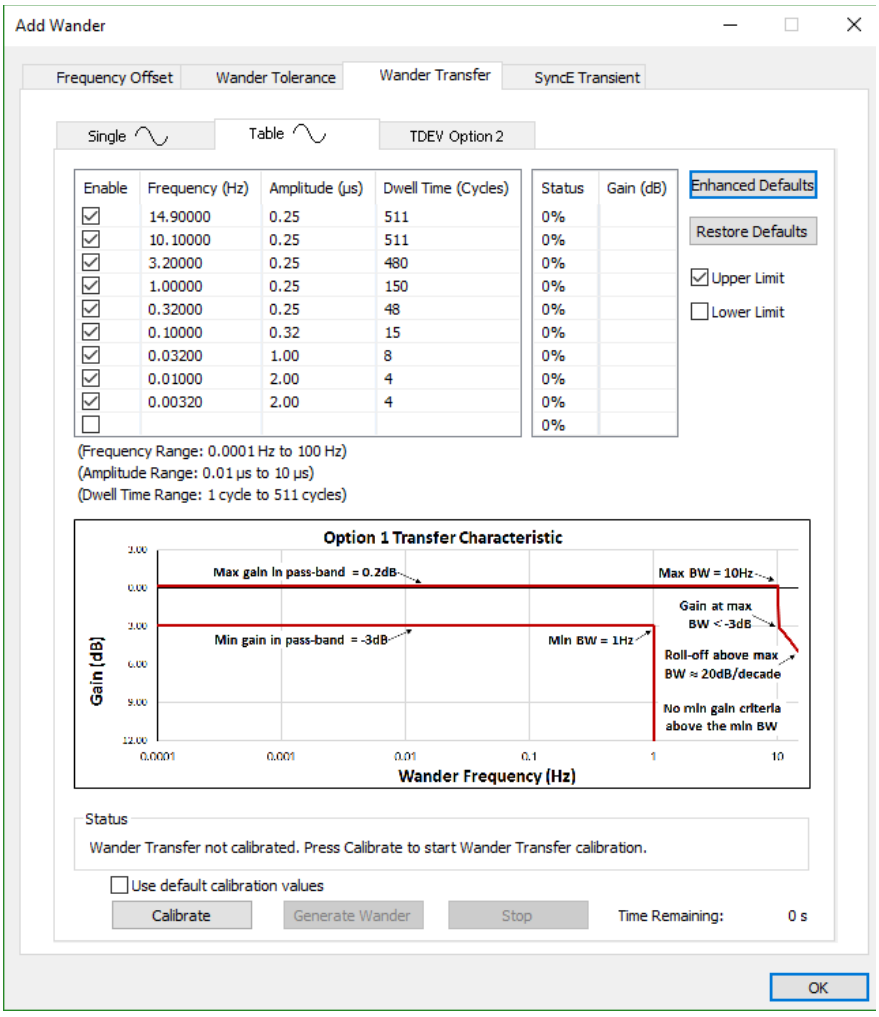
a) Select the ***Table*** tab:



b) There are several options available for wander transfer testing:

i. Suggested frequency/amplitude/dwell time sets are available as defaults. These may be used to determine performance within the passband of the EEC filter. When executed, each row includes a recovery period during which no measurement is made to avoid fails due to EEC transient response at frequency change-over.

ii. An extended frequency/amplitude/dwell time dataset is available by clicking the Enhanced Defaults button. This will populate and enable the values as shown in the screenshot and table below, which will test the performance of the EEC filter both in and out of its passband. When executed, each row includes a recovery period during which no measurement is made to avoid fails due to EEC transient response at frequency change-over.



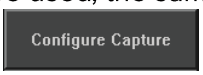
Frequency (Hz)	Amplitude (ns)	Dwell Time (Cycles)	Settling Time (s)
14.9	250	511	20
10.1	250	511	20
3.2	250	480	50
1	250	150	50
0.32	250	48	50
0.1	320	15	50
0.032	1000	8	50
0.01	2000	4	50
0.0032	2000	4	50

Check boxes ***Upper Limit*** and ***Lower Limit*** are provided to enable limit checking of the filter gain at each measured frequency. For more detail on this, and how to calculate valid parameters for other values, see **Appendix II SyncE Wander Transfer using Tones: EEC Option 1**

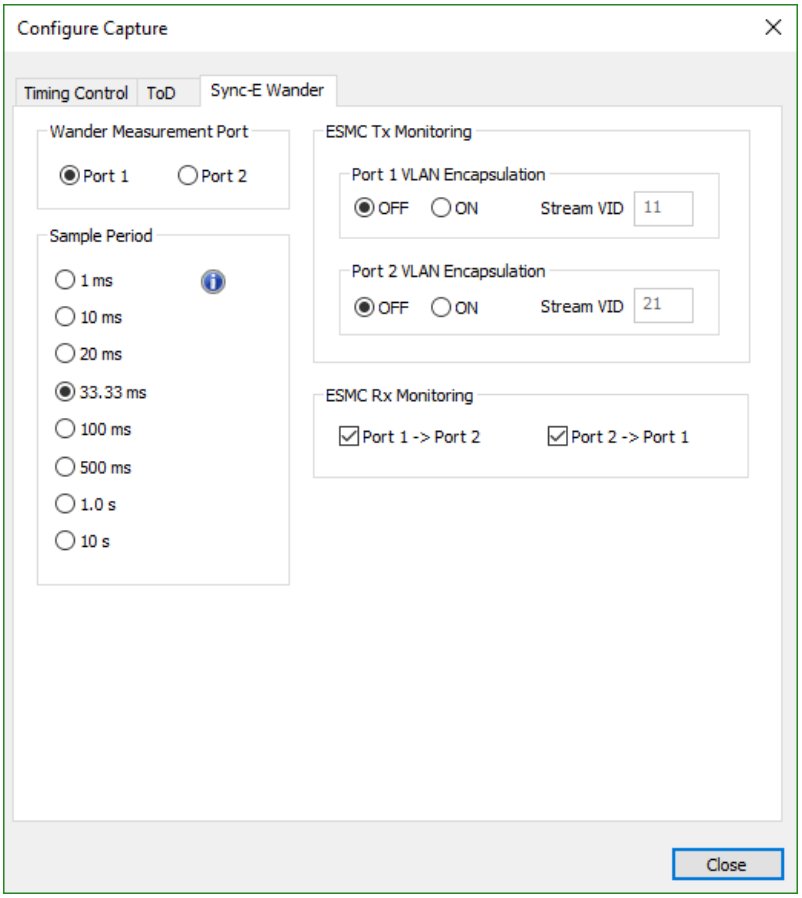
iii. User-selected values for frequency, amplitude and dwell time may be entered into the table. A warning will be displayed if the cycle count entered for a particular frequency

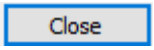
is not sufficient to include the necessary recovery and measurement time. The recovery time values are as stated in the table below:

Frequency (Hz)	Recovery Time (s)
>35	0
15 to 35	5
4 to 15	20
<4	50

Note: the sampling period can be configured in the ***Sync-E Wander*** tab of the ***Configure Capture*** dialogue. In order to avoid Nyquist effects, the sample period should be less than (1000/2*f*) ms where *f* is the configured maximum frequency in Hz. If frequencies higher than 14.9Hz are to be used, the sample period should be reduced from the default of 33.33ms by clicking 

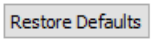
and selecting an appropriate value from the displayed list:



Click 

to return to the Wander Transfer dialogue.

Notes:

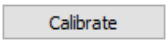
- The 

button can be used to restore the values to those defined in table 9 of ITU-T G.8262.

- The test will execute only those rows which have the ***Enable*** checkbox ticked. To skip a selection, clear the ***Enable*** checkbox for that row.

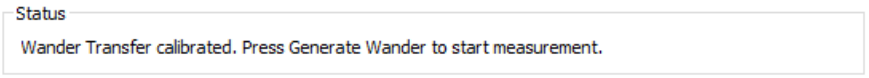
Calibration

Manual calibration is not essential, but may be performed if desired to calibrate Paragon-X prior to running the SyncE wander transfer test. Manual calibration may result in a more accurate gain calculation.

a) To perform a calibration, connect a short ethernet cable between Port 1 and Port 2 and click the 

button. Note: the duration of this calibration is dependent on the frequency/cycle pairs selected by the ***Enable*** checkboxes and may take several hours. For the ***Enhanced Defaults*** configuration, it will take around 40 minutes.

b) The Status area will indicate when the calibration is complete:

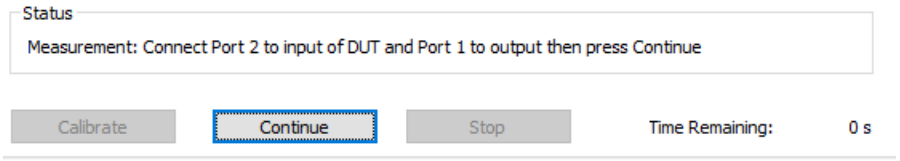


c) Remove the ethernet cable between port 1 and port 2 and connect the EEC to be tested as shown in the setup diagram at the start of this section, then continue with instructions below.

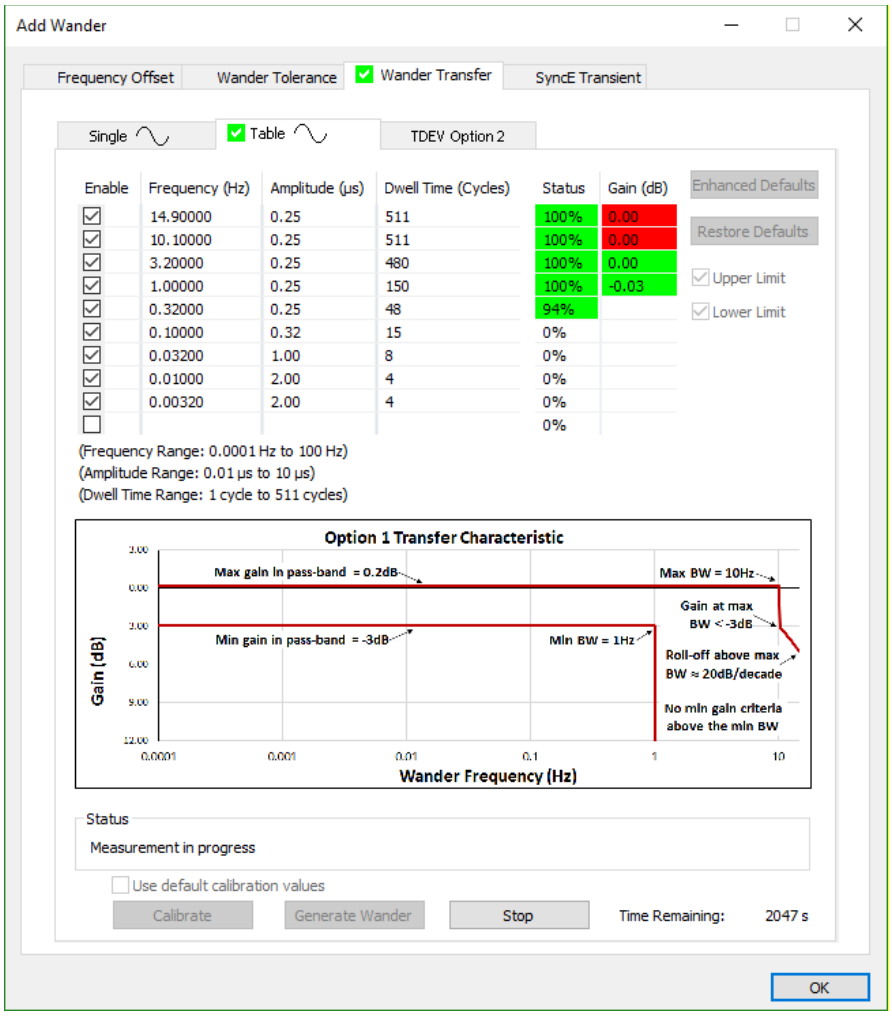
Test execution

a) Click the 

button to start the test. The Status area will update to indicate the EEC should now be connected; confirm this is true, then click ***Continue*** to start the test:



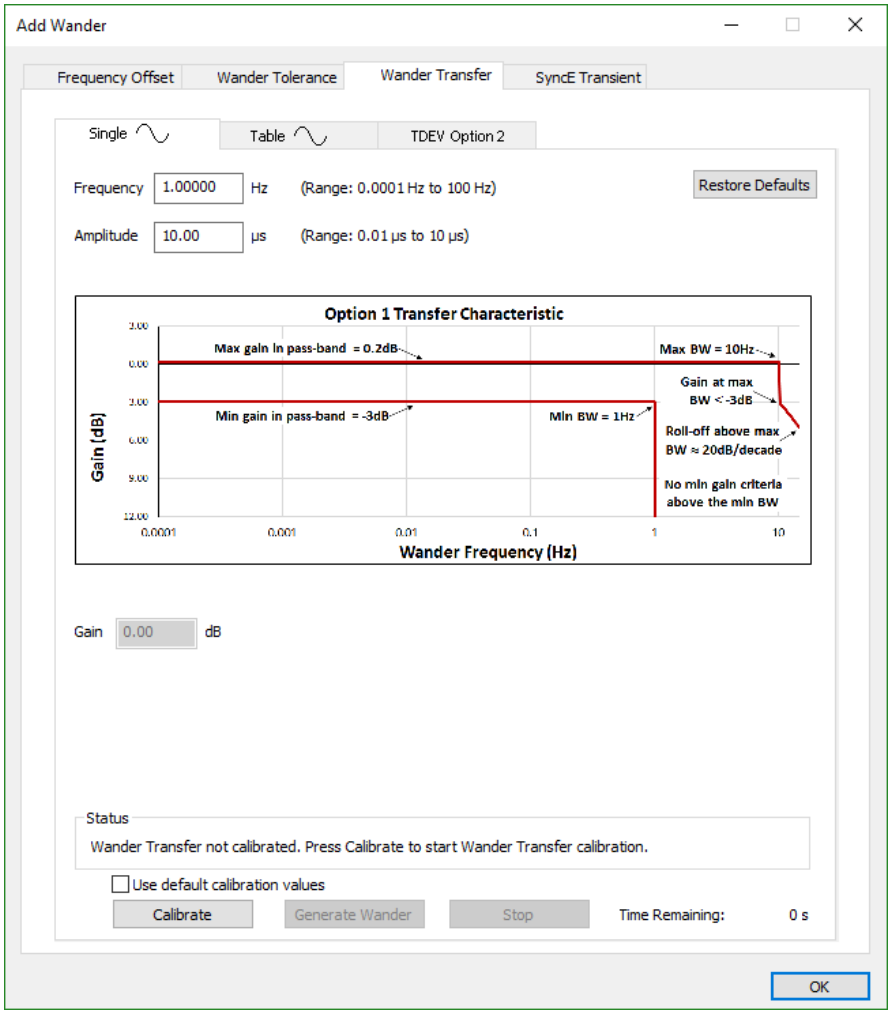
b) Paragon-X will show the test progress, the measured Gain (dB) and Pass/Fail (indicated by green or red shading, respectively) on the right hand side of the window. A pass is achieved if the measured amplitude is within the applied limits at each frequency, the values for which can be found in **Appendix II SyncE Wander Transfer using Tones: EEC Option 1**



10.2.2 G.8262 Option 1 Wander Transfer Test: Paragon-X single frequency test

This capability can be used for fault finding of issues at specific frequencies.

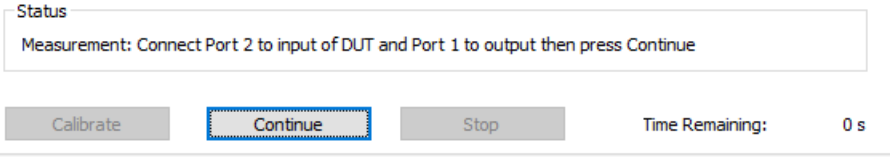
a) Select the ***Single*** tab.



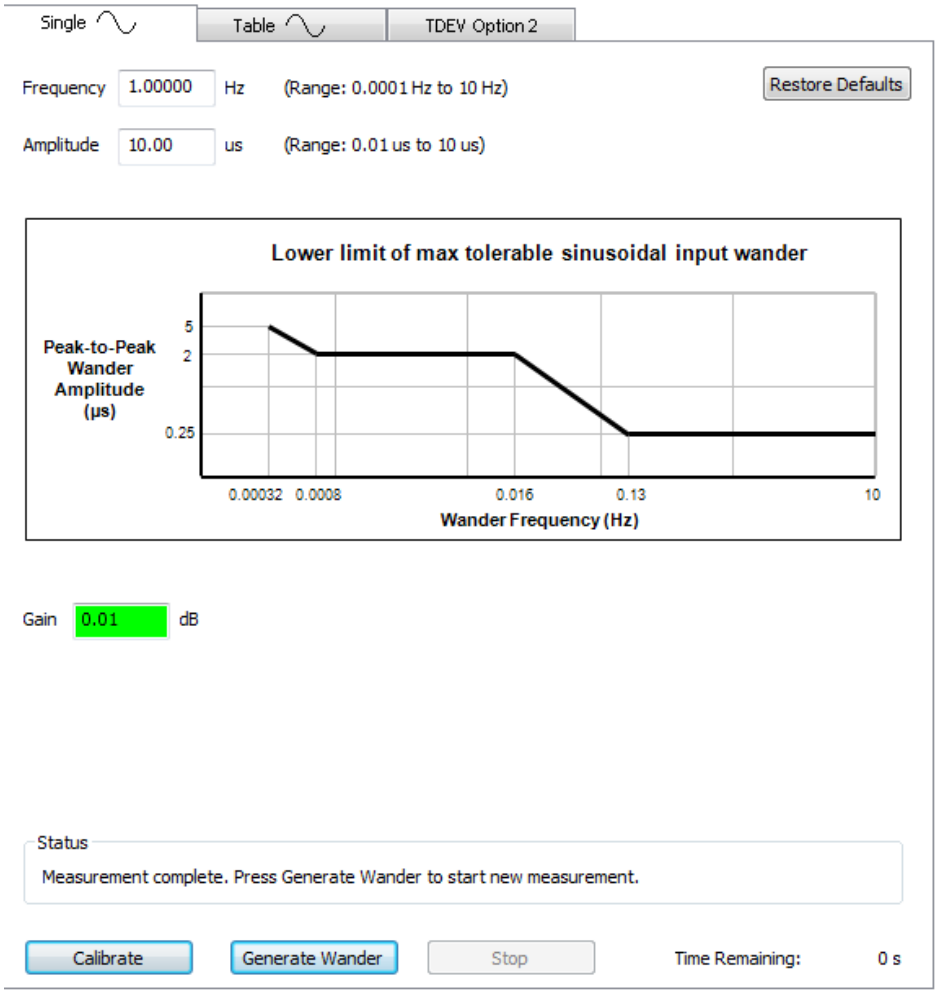
b) Enter the frequency and amplitude of the wander to be generated.

c) If calibration is desired, follow the instructions in the Calibration section of the Table Wander Transfer section.

d) Click the Generate Wander button to start the test. The Status area will update to indicate the EEC should now be connected; confirm this is true, then click Continue to start the test:

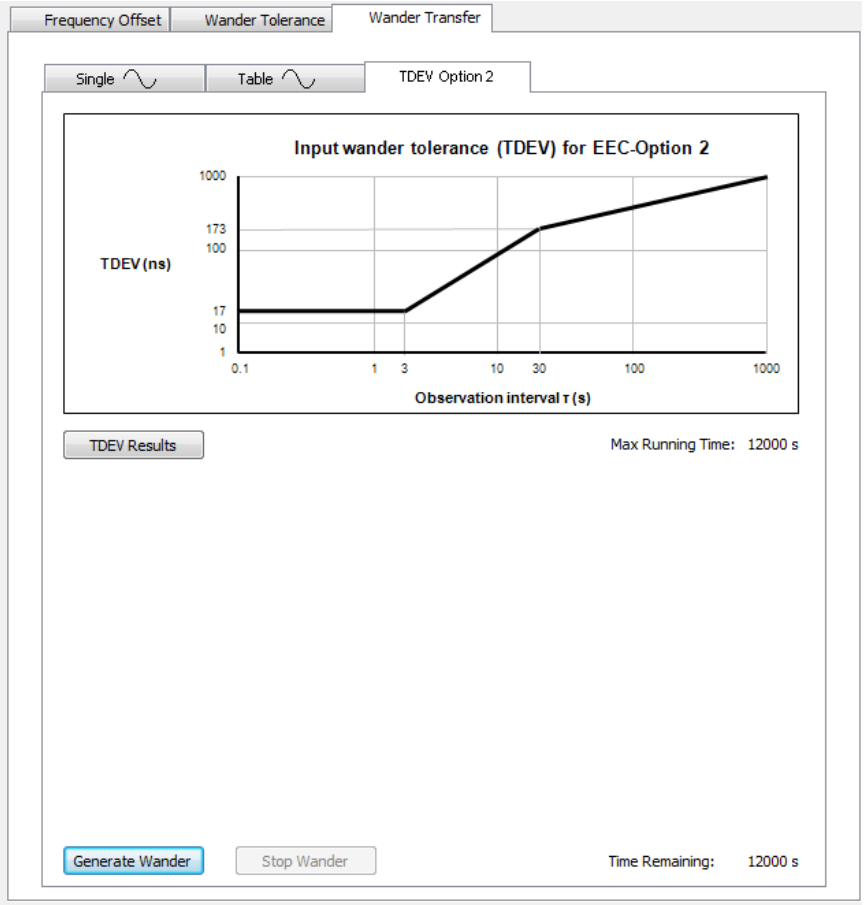


e) The GUI will show the estimated time remaining at the bottom of the screen. A Pass/Fail indication (shown by a green or red background respectively) will be displayed based on the measured amplitude.



10.2.3 G.8262 Option 2 Wander Transfer Test

a) Select the ***TDEV Option 2*** tab. This will display `G.8262 TDEV Wander Tolerance for EEC-Option 2` mask.



b) Press the Generate Wander button to start the test.

c) The amount of the time until completion of the test is shown at the bottom right hand side of the screen. The test has a run duration of 12000s (3h 20m).

d) At any time during the test, it is possible to view an updated output `TDEV` graph by clicking the TDEV Results button. This will launch CAT. Use the Select Metrics button to select the `TIE`, `MTIE` and `TDEV` metrics, then click Calculate and View Results to display the live capture metrics:

e) Select the ***TDEV*** tab, then select the ***G.8262 EEC Opt.2 Wander Transfer*** mask from the masks dropdown menu in the bottom-right corner. A pass or fail indication based on this mask will be displayed in the top-right corner:

11 Short Term Phase Transient Response – G.8262 Section 11.1

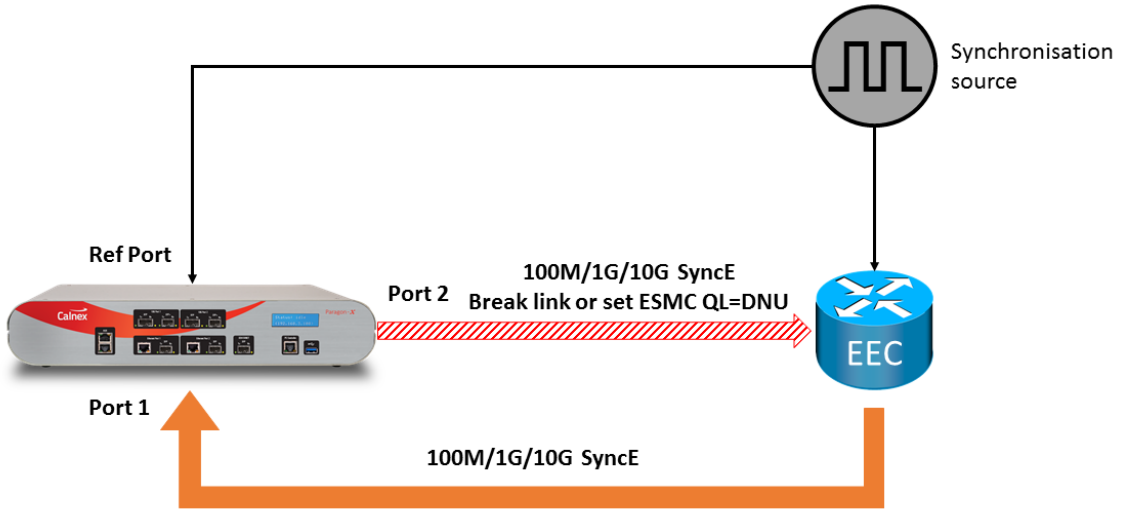
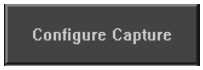


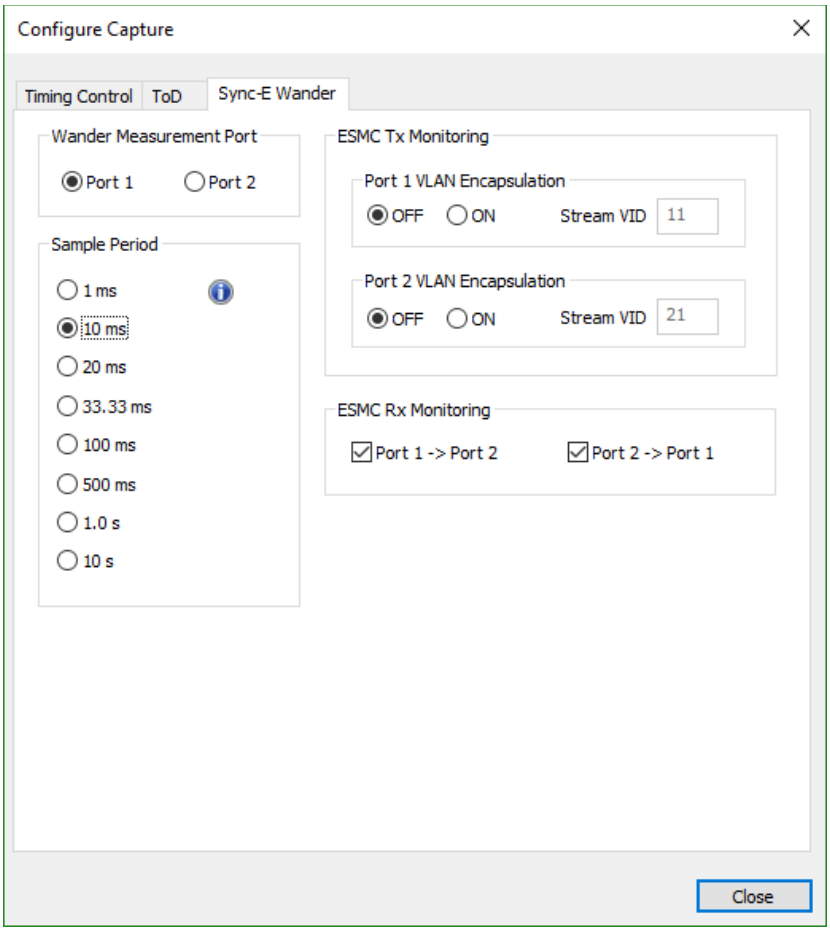
Figure 11: Phase Transient Response Test Set-Up

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	EEC input reference is lost for 15 seconds and a 2nd reference input signal, traceable to the same reference clock, is available simultaneously.	Maximum phase transient at the output due to reference switching to meet mask in G.8262 Figure 12	To emulate the loss of the link either change ESMC QL=DNU or remove the cable between port 2 and EEC
EEC Option 2	EEC input reference is lost for 15 seconds and a 2nd reference input signal, traceable to the same reference clock, is available simultaneously.	EEC output should meet MTIE mask defined by table 15/Figure 14 in section 11.4.2 of G.8262	To emulate the loss of the link either change ESMC QL=DNU or remove the cable between port 2 and EEC

11.1 Measurement Setup

a) Connect the EEC to Paragon-X as shown in the diagram at the beginning of this section
b) Set up Paragon-X as described in section 3, including enabling and starting ESMC generation with SSM=QL-PRC if using the ESMC method of switching clock references
c) Click the 

button and select the ***Sync-E Wander*** tab. Select ***10ms*** sample period then ***Close***.



11.2 Measurement Process

There are two methods for determining the Phase Transient Response with Paragon-X:

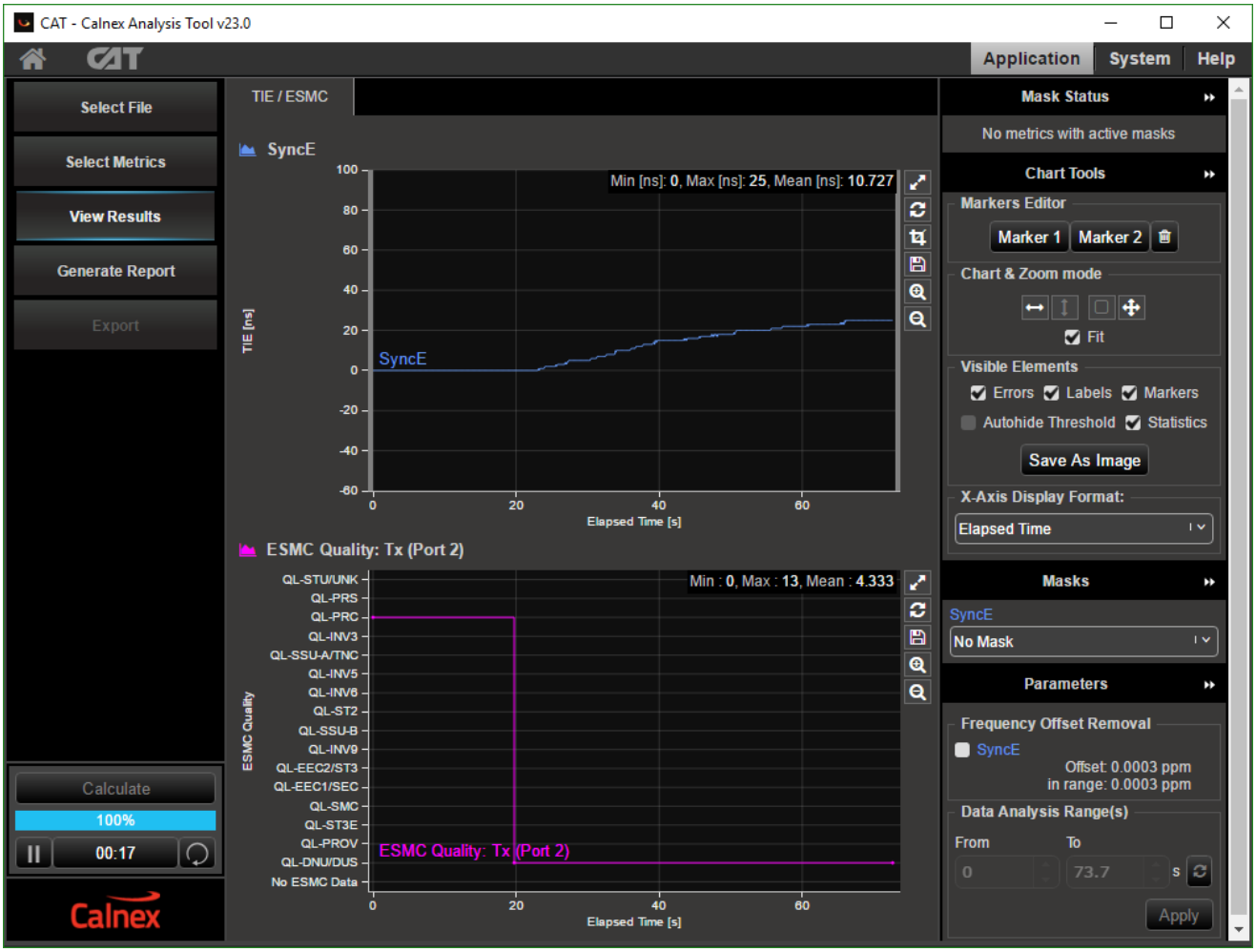
i. If supported by the EEC, modify the ESMC QL generated by Paragon-X to simulate the loss of a valid SyncE input, or
ii. Remove the link between Paragon-X port 2 and the EEC input port

To emulate the loss of link scenario by varying the input ESMC-QL:

a) Start the measurement by clicking the ***Start Capture*** button
b) Configure the generation of ESMC packets by clicking the ***Packet Generation*** button. Ensure the ***Port 2*** and ***Stream 1*** tabs are selected and that the ESMC SSM code is QL-PRC, then click the ***Start*** button. Observe the DUT behaviour.
c) When settled (locked), change the SSM code by selecting ***QL-DNU/DUS*** from the dropdown menu and click the ***Apply Change*** button.
d) Once DUT behaviour has been observed, click ***Stop Capture***

11.3 Measuring Results

The switching transient response can be seen on the Paragon-X graph, and may be further analysed in CAT. Launch CAT either from the ***Select Graph*** button or the ***Tools*** menu, then use ***Select Metrics*** to enable ***SyncE TIE*** and ***ESMC Quality: Tx (Port 2)***.



The method of evaluating phase transient response is dependent upon whether the DUT is an Option 1 or Option 2 EEC.

EEC Option 1

Evaluate the TIE measurement against a mask in CAT.

a) Select ***G.8262 EEC Opt.1 Short-term Phase Transient*** mask from the dropdown Masks menu.
b) Modify the Data Analysis Range values to align the start of the range with the timing of the change of ESMC-QL. This will align the mask timing with the measured TIE
c) A Pass/Fail indication will be shown in the top-right corner.

EEC Option 2

To view the output **MTIE** mask, which is only valid for Option 2 EEC:

a) If not already visible, launch CAT from the Select Graph button or the Tools menu, then use the **Select Metrics** button to enable `MTIE` and `TDEV` measurements
b) Select the **G.8262 EEC Opt.2 Short-term Phase Transient** mask from the **SyncE Masks** dropdown menu in the bottom-right corner
c) A pass or fail indication based on this mask will be displayed in the top-right corner:

Appendix I G.8262: Practical interpretation guidance

I.1 Frequency Accuracy – G.8262 Section 6

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	Free run	+/- 4.6 ppm	Recommend to test for an hour, longer if close to limits
EEC Option 2	Hold over	+/- 4.6 ppm	Recommend to test for an hour, longer if close to limits

I.2 Pull–in Range (G.8262 Section 7.1)

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1 and EEC Option 2	Apply a large Frequency offset ensuring EEC is in holdover. Reduce offset until EEC locks.	• EEC starts unlocked with large offset applied • EEC locks before offset reaches +/- 4.6ppm	Lock can also be monitored by using ESMC (if supported)

I.3 Hold–in Range (G.8262 Section 7.2)

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	Not Applicable		
EEC Option 2	EEC is locked to the clock from the Paragon-X. The frequency is then offset to +/-4.6ppm	EEC should remain locked at an offset at +/-4.6ppm	Lock can also be monitored by using ESMC (if supported)

I.4 Pull–out Range (G.8262 Section 7.3)

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	EEC is locked to the clock from the Paragon-X. The frequency is then offset until the EEC unlocks.	EEC should remain locked at an offset at +/-4.6ppm but lock should extend beyond this.	G.8262 states this is for further study
EEC Option 2	Not Applicable		

I.5 Wander Generation (G.8262 Section 8)

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1 (Constant Temp)	• Locked Mode • Wander free reference • Constant temperature	MTIE & TDEV Pass/Fail masks shown in G.8262 Section 8.1.1	MTIE – Table 1/ Figure 1 TDEV – Table 3/ Figure 2
EEC Option 1 (Temp effects)	• Locked Mode • Wander free reference • Temperature effects	MTIE Pass/Fail masks shown in G.8262 Section 8.1.2.	MTIE – Table 1/ Figure 1 TDEV – G.8262 states for further study
EEC Option 2 (Constant Temp)	• Locked Mode • Wander free reference • Constant temperature	MTIE & TDEV Pass/Fail masks shown in G.8262 Section 8.1.2	MTIE – Table 4/ Figure 3 TDEV – Table 5/ Figure 4

I.6 Wander Tolerance (G.8262 Section 9)

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	• MTIE Wander Table 7/Figure 5 • TDEV Wander Table 8/Figure 6 • Sinusoidal Wander Table 9/Figure 7	The EEC is; • Maintaining the clock within performance limits. • Not causing any alarms. • Not causing the clock to switch reference. • Not causing the clock to go into holdover.	To check whether the EEC is switching references or going into holdover, the Paragon can measure the wander and/or ESMC QL of the EEC output.
EEC Option 2	• TDEV Wander Table 10/Figure 8 •	The EEC is;. • Maintaining the clock within performance limits • Not causing any alarms. • Not causing the clock to switch reference. • Not causing the clock to go into holdover.	To check whether the EEC is switching references or going into holdover, the Paragon can measure the wander and/or ESMC QL of the EEC output.

Wander Transfer (G.8262 Section 10)

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	Not defined	The phase gain of the EEC should be smaller than 0.2 dB (2.3%).	There is no definition of the input stimulus to be used in G.8262. Without further guidance from the Standards, it is suggested that the amplitude and frequency values associated with mask points labelled f1, f2 & f3 on G.8262 Section 9.1.1, Table 9 & Figure 7 are used.
EEC Option 2	TDEV Wander Table 10/Figure 8	Measure EEC output against TDEV Pass/Fail masks shown in G.8262 Section 10..2 Table 13/Figure 11	

I.7 Short Term Phase Transient Response (G.8262 Section 11.1)

	Input Stimulus	Pass/Fail Criteria	Notes
EEC Option 1	EEC input reference is lost for 15 seconds and a 2nd reference input signal, traceable to the same reference clock, is available simultaneously	Maximum phase transient at the output due to reference switching to meet mask in G.8262 Figure 12	To emulate the loss of the link either • Change ESMC QL=DNU • Remove the cable between port 2 and EEC
EEC Option 2	EEC input reference is lost for 15 seconds and a 2nd reference input signal, traceable to the same reference clock, is available simultaneously	EEC output should meet MTIE mask defined by table 15/ Figure 14 in section 11.4.2 of G.8262	To emulate the loss of the link either: • Change ESMC QL=DNU • Remove the cable between port 2 and EEC

Appendix II SyncE Wander Tolerance using Tones: EEC Option 1

The frequencies used must be chosen carefully to avoid Nyquist effects due to sampling. The selected frequencies and corresponding amplitudes are shown in the table below.

Parameters used:

- Measured at each corner point in G.8262/Figure 7
- At least one point per decade

Frequency (Hz)	MTIE Observation Interval (s)	Amplitude (ns)	Test Time (Cycles)	Test Time (s)
10	0.032	250	1500	150
1	0.32	250	150	150
0.13	2.5	250	20	154
0.016	20	2000	4	250
0.0032	100	2000	4	1250
0.0008	400	2000	3	3750
0.00032	1000	5000	3	9375

Table 9 – Lower limit of maximum tolerable sinusoidal input wander for EEC-Option 1

Peak-to-peak wander amplitude			Wander frequency				
A_1 [µs]	A_2 [µs]	A_3 [µs]	f_4 [mHz]	f_3 [mHz]	f_2 [mHz]	f_1 [Hz]	f_0 [Hz]
0.25	2	5	0.32	0.8	16	0.13	10

The resultant requirements are shown in Figure 7.

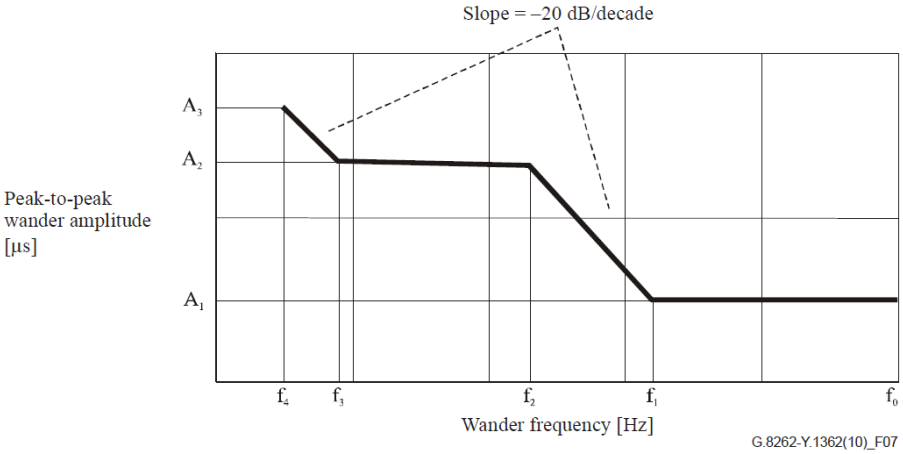


Figure 7 – Lower limit of maximum tolerable sinusoidal input wander for EEC-Option 1

Appendix III SyncE Wander Transfer using Tones: EEC Option 1

The frequencies used must be chosen carefully to avoid Nyquist effects due to sampling. The selected frequencies and corresponding amplitudes are shown in the table below. The amplitudes increase at lower frequencies to provide an increased signal-to-noise ratio.

The filter characteristics are not specified in the relevant standards. To set pass/fail limits, the following assumptions have been made:

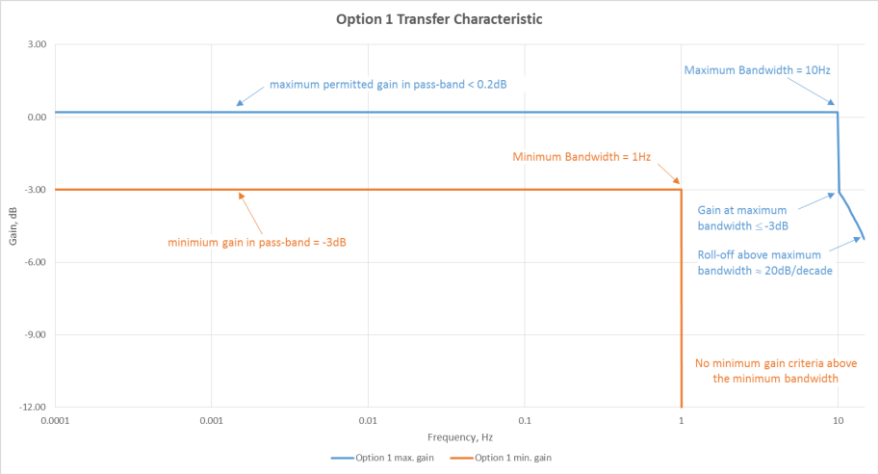
- The minimum gain in the passband is -3dB
- The filter is first-order, with a roll-off of 20dB/decade

In addition, 20ns is included in the limits as allowance for the inherent noise generation of the DUT.

Parameters used:

- Maximum bandwidth: 10Hz
- Minimum bandwidth: 1Hz
- Maximum gain peaking: 0.2dB
- Minimum gain in pass-band: -3dB
- Noise generation allowance: ±20ns
- Two points per decade, extending more than 2 decades below the -3dB point

Frequency (Hz)	Amplitude (ns)	Test Time (Cycles)	Test Time (s)	Max. Gain (dB)	Min. Gain (dB)	Max. Output Amplitude (ns)	Min. Output Amplitude (ns)
14.9	250	2235	150	-5.1	none	160	none
9.9	250	1485	150	-3.0	none	198	none
3.2	250	480	150	0.2	none	276	none
1	250	150	150	0.2	-3.00	276	156
0.32	250	48	150	0.2	-3.00	276	156
0.1	320	15	150	0.2	-3.00	348	206
0.032	1000	8	250	0.2	-3.00	1044	687
0.01	2000	4	400	0.2	-3.00	2067	1395
0.0032	2000	4	1250	0.2	-3.00	2067	1395



Appendix IV SyncE Wander Tolerance using Tones: EEC Option 2

Parameters used:

- Measured at each corner point in G.8262/Figure 7
- At least one point per decade

Frequency (Hz)	MTIE Observation Interval (s)	Amplitude (ns)	Test Time (Cycles)	Test Time (s)
3.2	0.1	300	480	150
0.32	1	303	150	150
0.032	10	325	8	250
0.0032	100	550	4	1250
0.0011	280	1000	3	2727
0.00032	1000	1007	3	9375

Table 5/G.824 – MTIE limit for 1544 kbit/s reference signals

Observation interval, τ (seconds)	MTIE (ns)
$0.05 \leq \tau \leq 280$	$300 + 2.5\ \tau$
$280 < \tau$	$997 + 0.01\ \tau$

The resulting overall specification is illustrated in Figure 3.

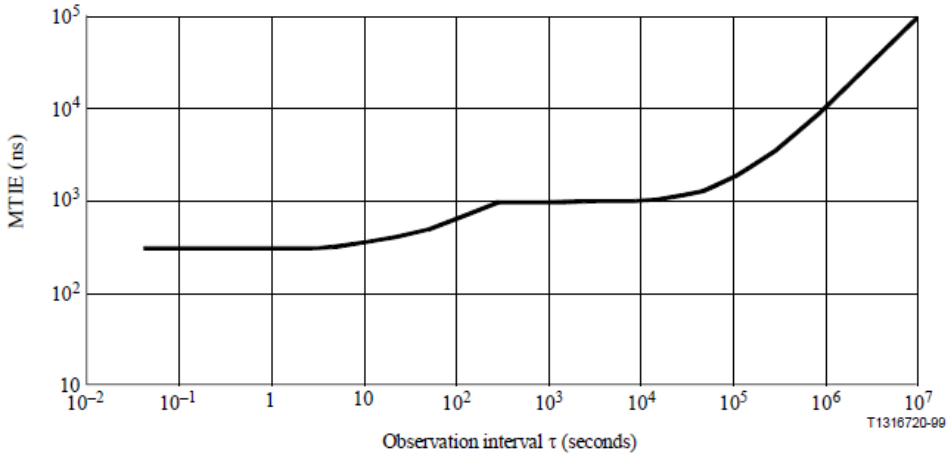


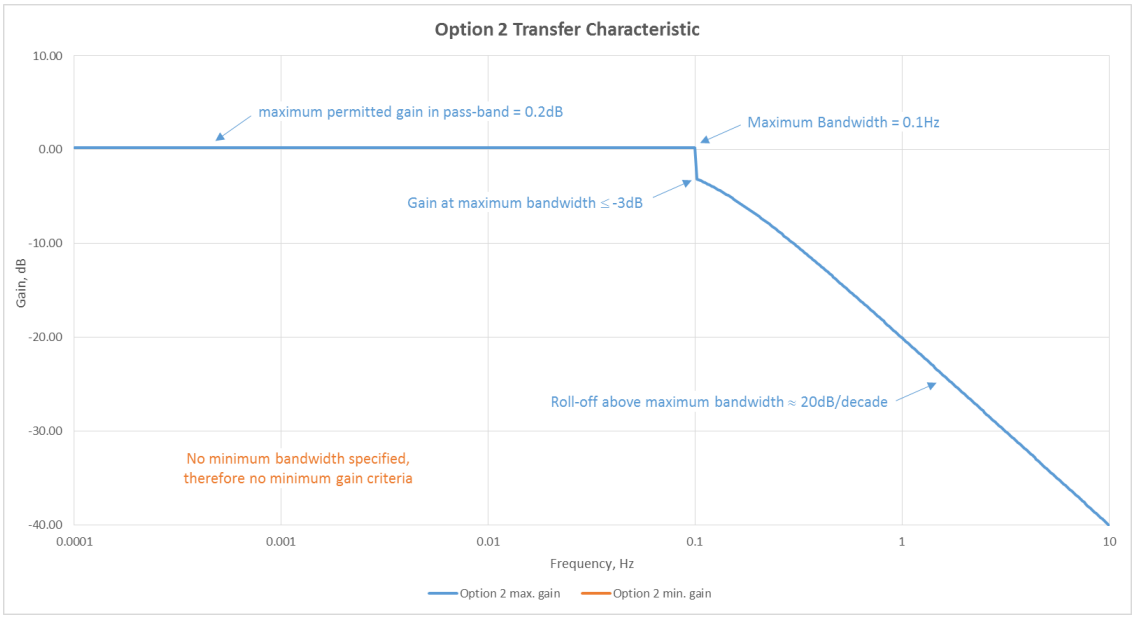
Figure 3/G.824 – MTIE limit for 1544 kbit/s reference signals

Appendix V SyncE Wander Transfer using Tones: EEC Option 2

Parameters used:

- Maximum bandwidth: 0.1Hz
- Minimum bandwidth: none specified
- Maximum gain peaking: 0.2dB
- Minimum gain in pass-band: no criteria, since no minimum bandwidth specified
- Noise generation allowance: ±20ns
- Two points per decade, extending over 2 decades below the -3dB point

Frequency (Hz)	Amplitude (ns)	Test Time (Cycles)	Test Time (s)	Max. Gain (dB)	Min. Gain (dB)	Max. Output Amplitude (ns)	Min. Output Amplitude (ns)
3.2	300	480	150	-30.1	none	30	none
1	301	150	150	-20.0	none	50	none
0.32	303	48	150	-10.5	none	111	none
0.1	308	15	150	-3.0	none	238	none
0.032	325	8	250	0.2	none	353	none
0.01	380	4	400	0.2	none	409	none
0.0032	550	4	1250	0.2	none	583	none
0.001	1000	3	3000	0.2	none	1044	none
0.00032	1007	3	9375	0.2	none	1051	none



For more information on the Calnex Paragon-X and to take advantage of Calnex's extensive experience in sync and packet testing technologies, please contact Calnex Solutions on +44 (0) 1506 671 416 or email: info@calnexsol.com

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