IEC/IEEE 60802 Clock noise model

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Introduction

- The presentation 60802-Lv-Rodrigues-clock-filter-0921-v00.pdf introduced a general clock filter model, and provided two points for the simulation models,
  ① Propose the end-point filter bandwidth, which is used by simulation, to be equal or less than 1/10 times of the Sync message rate;
  ② Consider the effect of the local oscillator to the end-point clock
- For the second point, it’s proposed to analyse the random noise of the local oscillator or clock, and the existing ITU-T model could be referred.

Oscillator phase noise model:

$$x(t) = A + B(t)\times t + C(t)\times t^2 + R(t)$$

Constant phase error

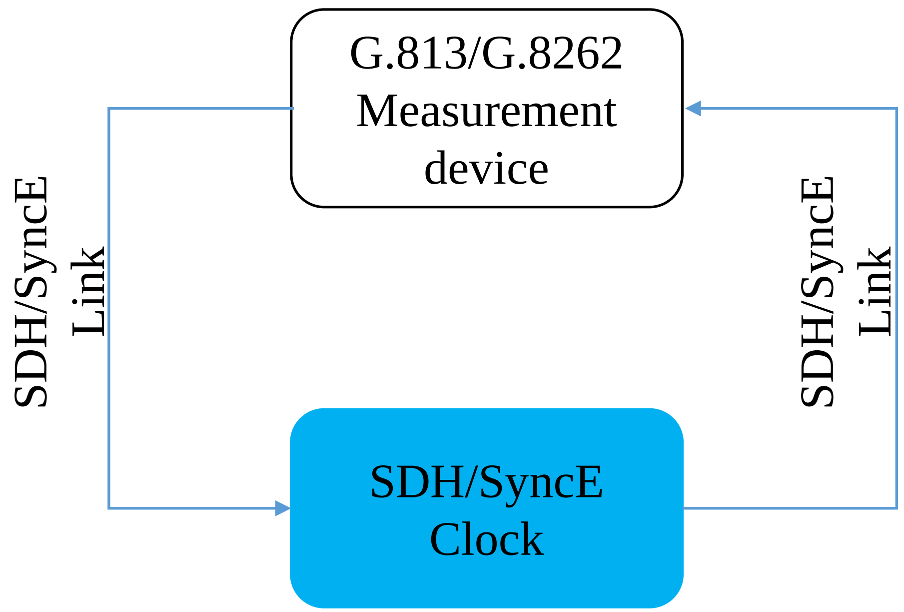
Aging: long-term variation of frequency offset

Frequency offset, variable with temperature

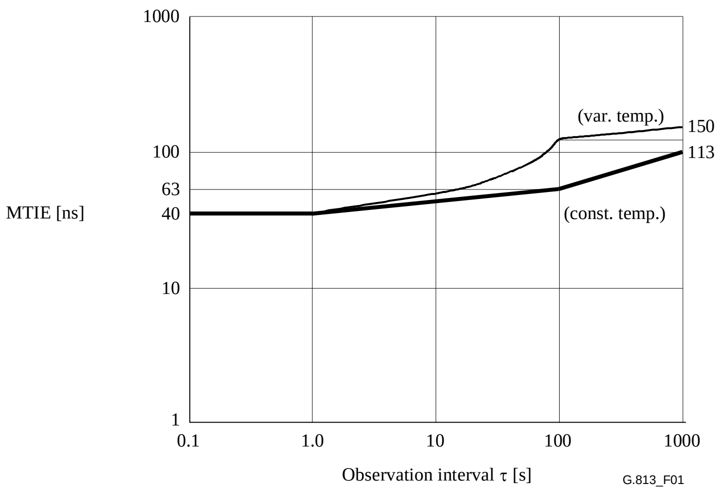
Random phase noise

Clock noise model

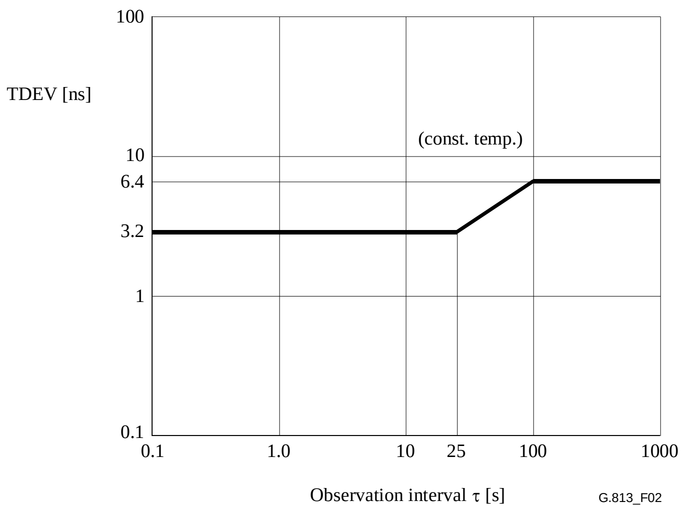
- ITU-T G.813 and G.8262 specify requirements for the SDH clock and SyncE clock respectively. One of them is the wander noise generation (see Clause 7.1 of ITU-T G.813 and Clause 8.1 of G.8262, they're same.)
- G.813/G.8262 includes Option 1 and Option 2 clocks, and Option 1 clock is widely used in telecom networks. This presentation is based on Option 1 clock.



- The output of SDH/SyncE clock should meet the below MTIE/TDEV masks.

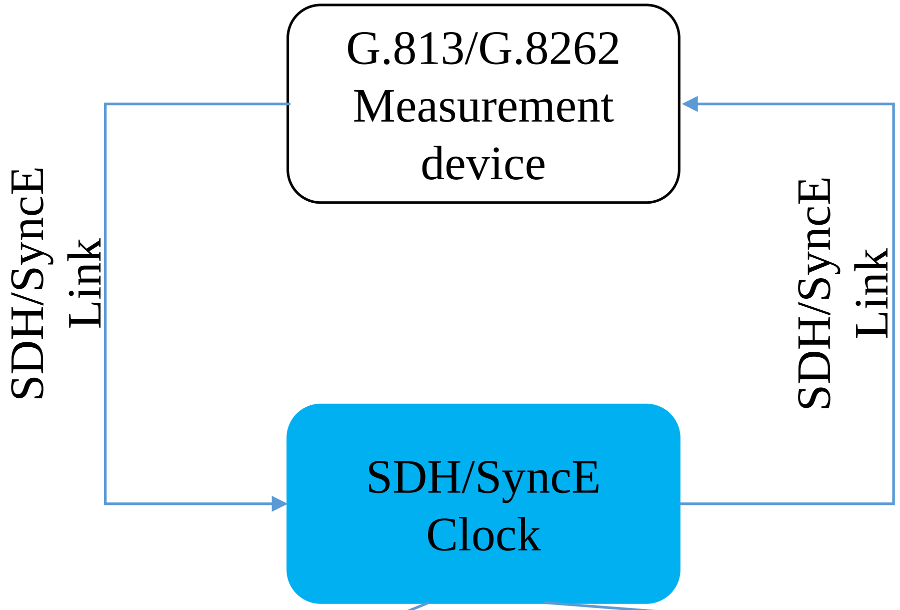


Option 1 MTIE mask



Option 1 TDEV mask

Clock noise model



- Noise transfer function of the model:

$$Y = X \times H + N \times (1 - H)$$

H is a low-pass filter, and (1 – H) is a high-pass filter

- The output signal Y should meet the MTIE/TDEV masks in the previous page.
- Due that the input signal X generated by the measurement device is ideal (assumed to be zero), then

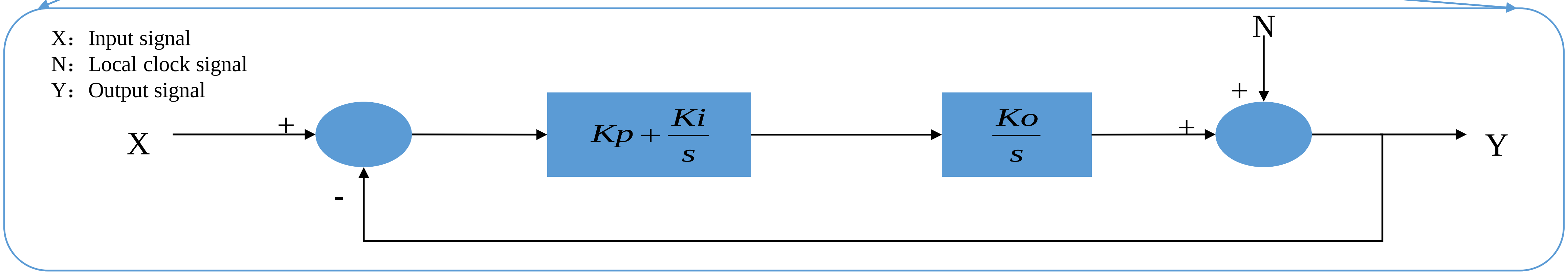
$$Y = N \times (1 - H)$$

- And the local clock signal N is,

$$N = \frac{1}{1 - H} \times Y$$

1/(1 – H) is a reverse high-pass filter

A mathmetical model of SDH/SyncE clock



Clock noise model

- Therefore, if the noise data Y is based on the MTIE/TDEV masks, the local clock noise data N can be calculated via the previous model,

$$N = \frac{1}{1-H} \times Y$$

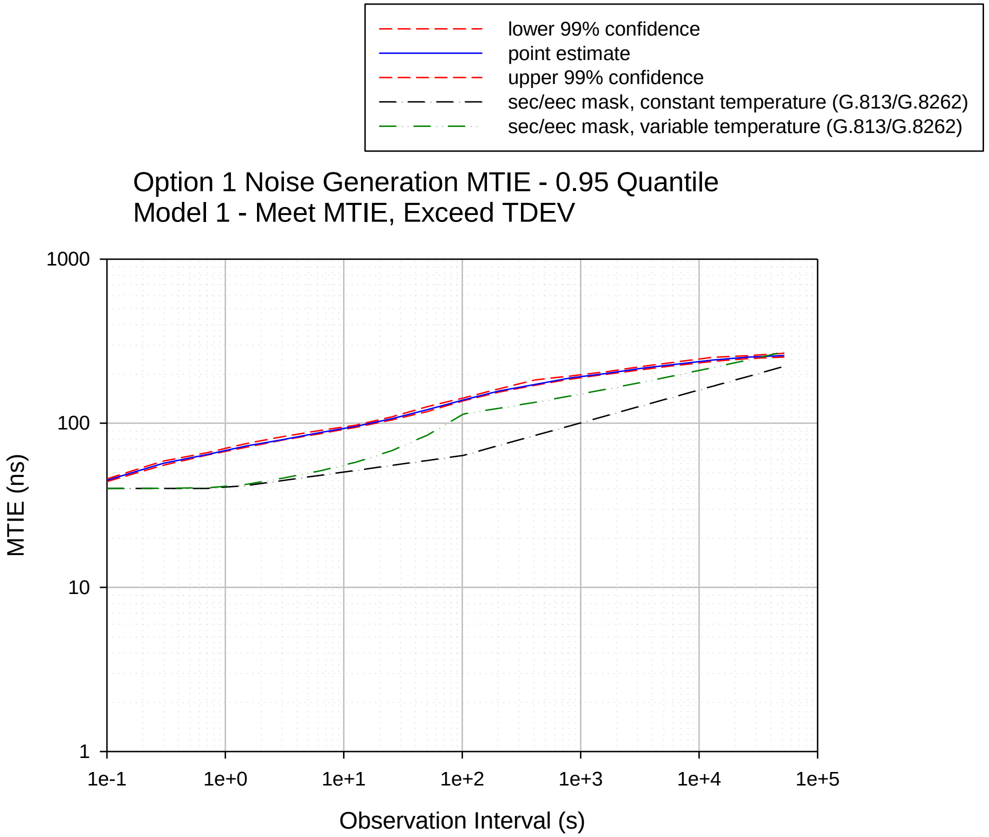
- ITU-T G.Sup.65 has provided three models to get the noise data Y, in order to comply with the MTIE/TDEV masks as best as possible.
  - Option 1, Model 1, Clause 8.1.2.1 of ITU-T G.Sup.65
  - Option 1, Model 2, Clause 8.1.2.1 of ITU-T G.Sup.65
  - Option 1 ETSI model, Clause 8.1.4.1 of ITU-T G.Sup.65

Clock noise model

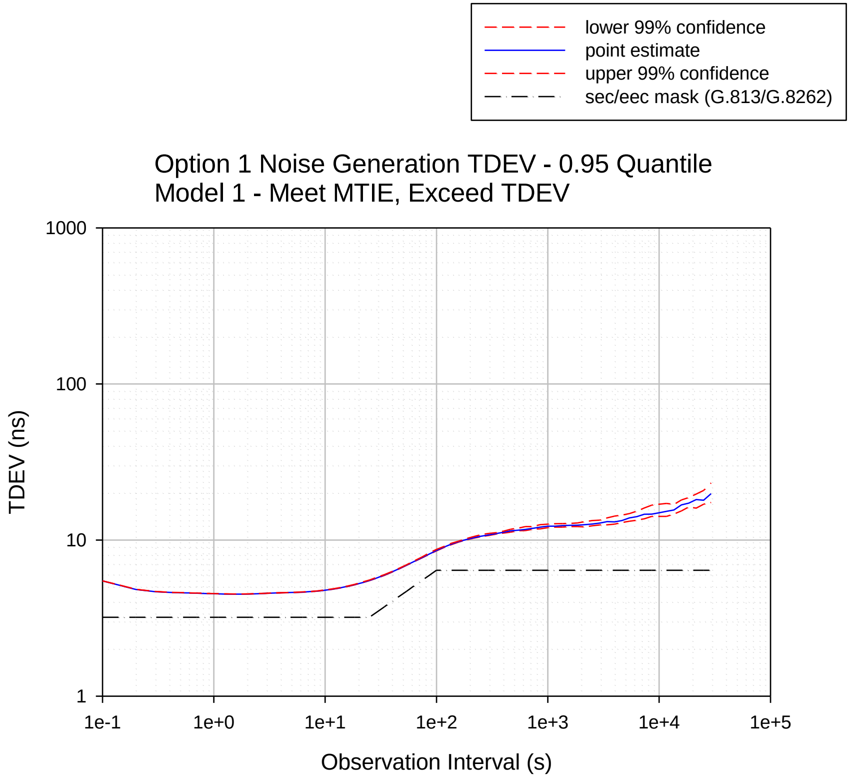
- Option 1, Model 1: meets variable-temperature MTIE mask, exceeds TDEV mask;
- The noise generation data below is generated by the combination of noise sources listed in table 6.

Table 6 – Noise source parameters for Option 1, Model 1
(meets variable-temperature MTIE mask, exceeds TDEV mask)

Noise source	Input white noise standard deviation (ns)	Low-pass filter bandwidth (Hz)	High-pass filter bandwidth (Hz)
WPM	0.0	–	–
WFM	2.450	–	3.183×10^{-3}
FPM1	7.336	–	–
FPM2	15.96	3.183×10^{-3}	–



MTIE, Figure 5 of ITU-T G.Sup.65



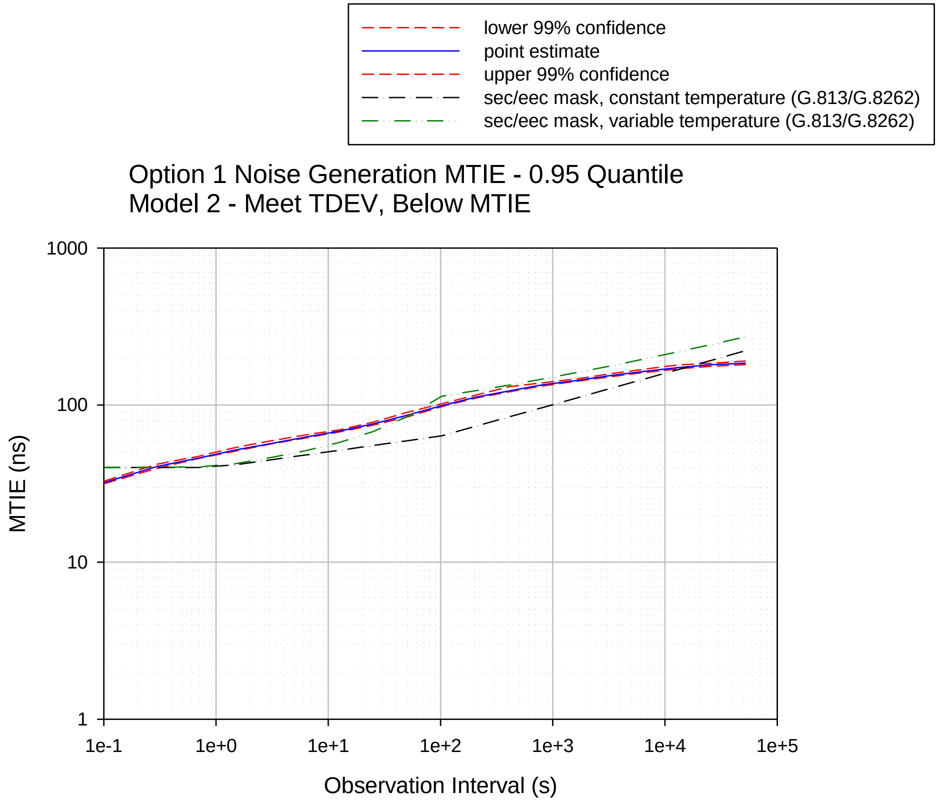
TDEV, Figure 6 of ITU-T G.Sup.65

Clock noise model

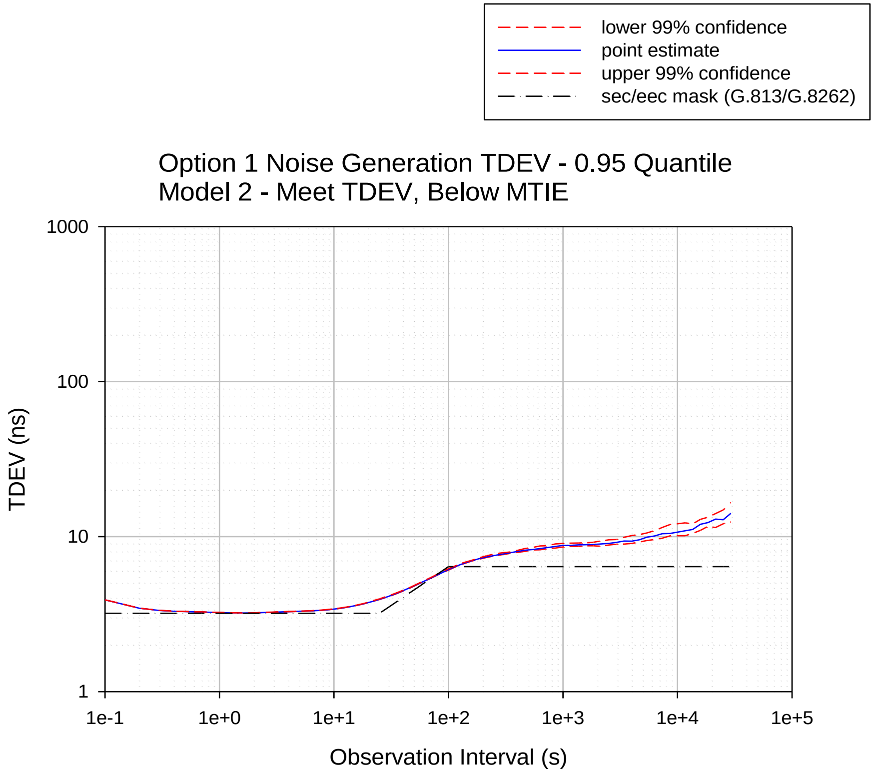
- Option 1, Model 2: meets TDEV mask as closely as possible, falls below variable-temperature MTIE mask;
- The noise generation data below is generated by the combination of noise sources listed in table 7.

Table 7 – Noise source parameters for Option 1, Model 2
(meets TDEV mask, falls below variable-temperature MTIE mask)

Noise source	Input white noise standard deviation (ns)	Low-pass filter bandwidth (Hz)	High-pass filter bandwidth (Hz)
WPM	0.0	–	–
WFM	1.750	–	3.183×10^{-3}
FPM1	5.240	–	–
FPM2	11.40	3.183×10^{-3}	–



MTIE, Figure 7 of ITU-T G.Sup.65



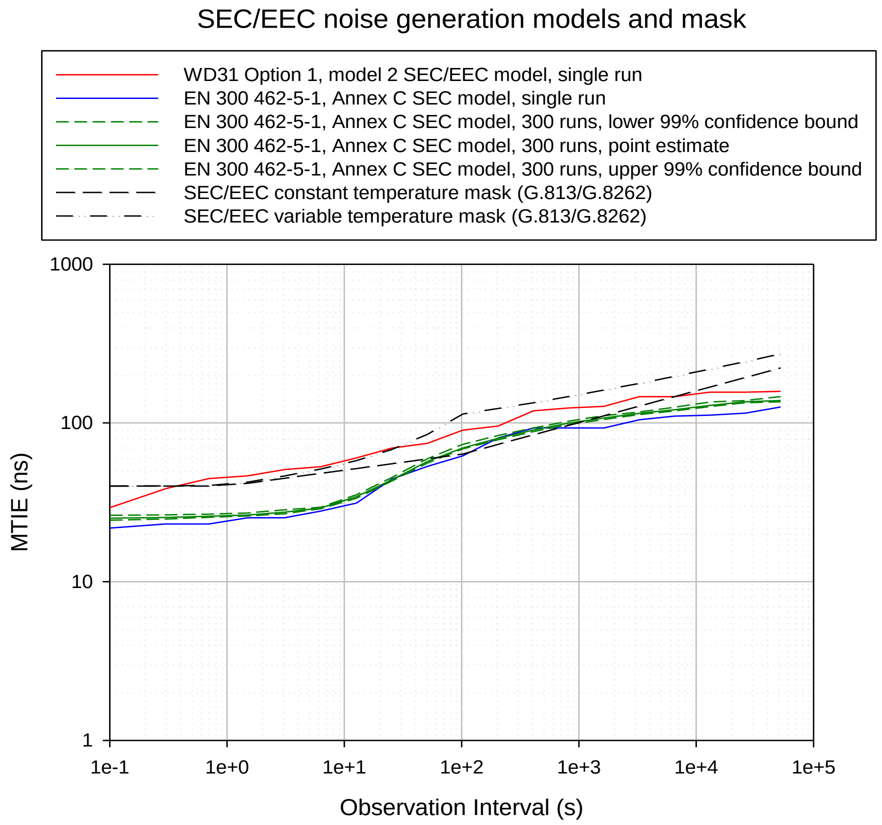
TDEV, Figure 8 of ITU-T G.Sup.65

Clock noise model

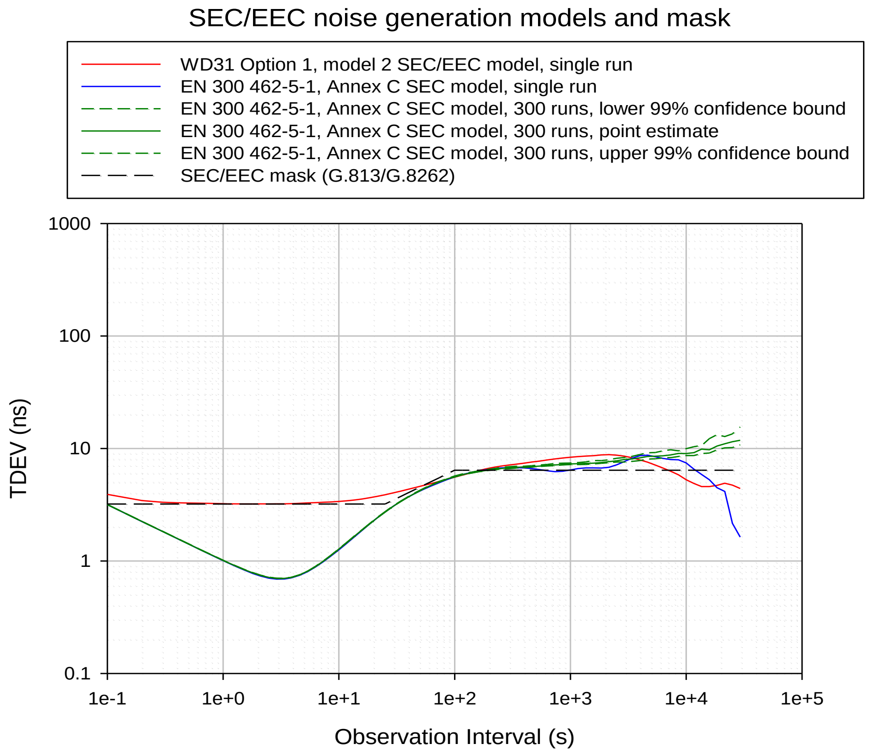
- Option 1, ETSI Model: matches the upper flat level and transition between lower and upper flat levels of the TDEV mask;
- The noise generation data below is generated by the combination of noise sources listed in table 23.

Table 23 – SEC/EEC noise model parameters, following ETSI SEC noise generation model (Annex C of [b-ETSI02])

Noise Source	Input white noise standard deviation (ns)	Low-pass filter bandwidth (Hz)	High-pass filter bandwidth (Hz)
WPM	1.0	–	0.006
FPM	10.67	0.006	–



MTIE, Figure 43 of ITU-T G.Sup.65



TDEV, Figure 44 of ITU-T G.Sup.65

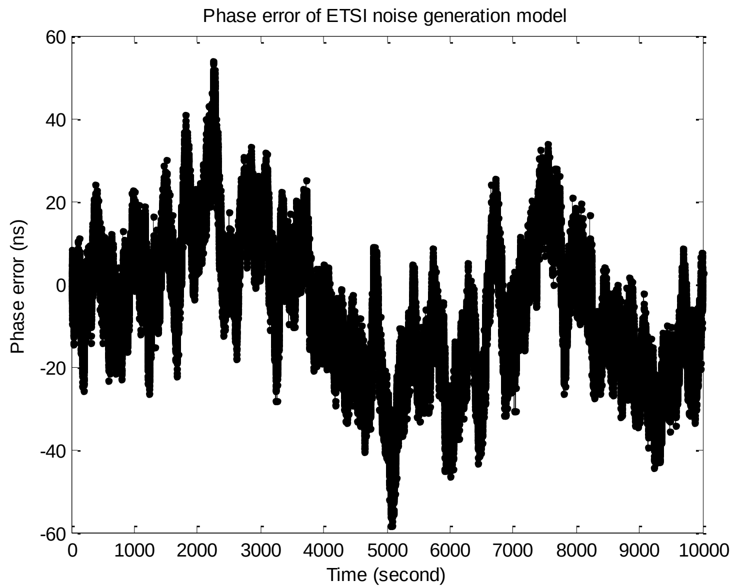
Clock noise model

- This presentation uses Option 1, ETSI model as assumption, considering it's used by ITU-T simulations.
- The below phase error data in the left figure is regenerated with the noises sources of table 23, and the simulation step is 0.1s.

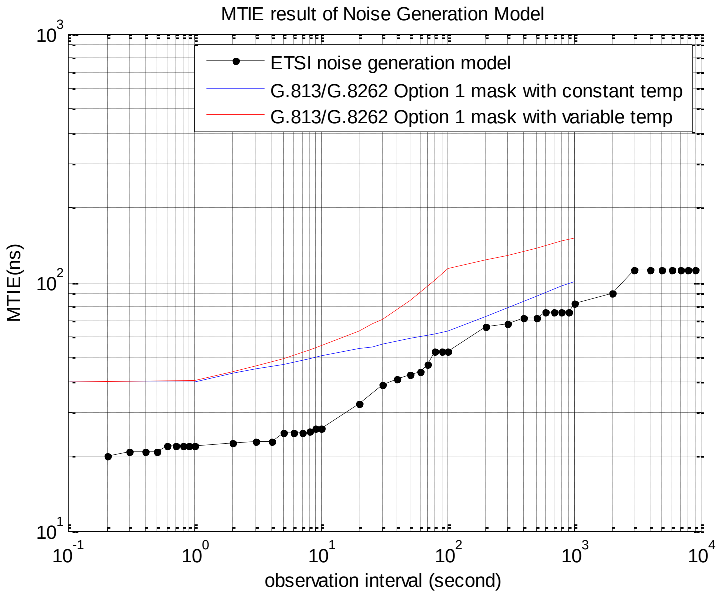
Table 23 – SEC/EEC noise model parameters, following ETSI SEC noise generation model (Annex C of [b-ETSI02])

Noise Source	Input white noise standard deviation (ns)	Low-pass filter bandwidth (Hz)	High-pass filter bandwidth (Hz)
WPM	1.0	–	0.006
FPM	10.67	0.006	–

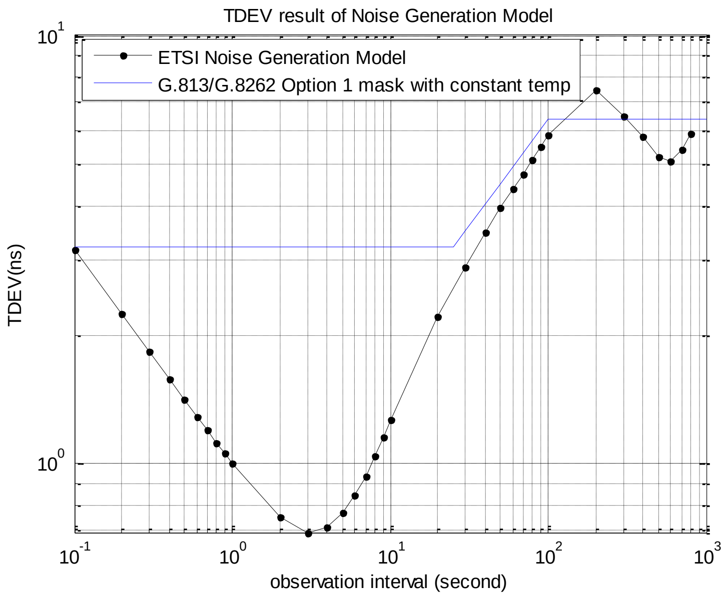
- Note, the below MTIE/TDEV figures only provide the result with a single run, and are not as smooth as the figures of ITU-T G.Sup.65, which shows the results with 300 runs.



Phase error



MTIE



TDEV

Clock noise model

- Using the reverse high-pass filter model *1/(1-H)* and the ETSI noise phase error *Y* to get the local clock noise *N*.

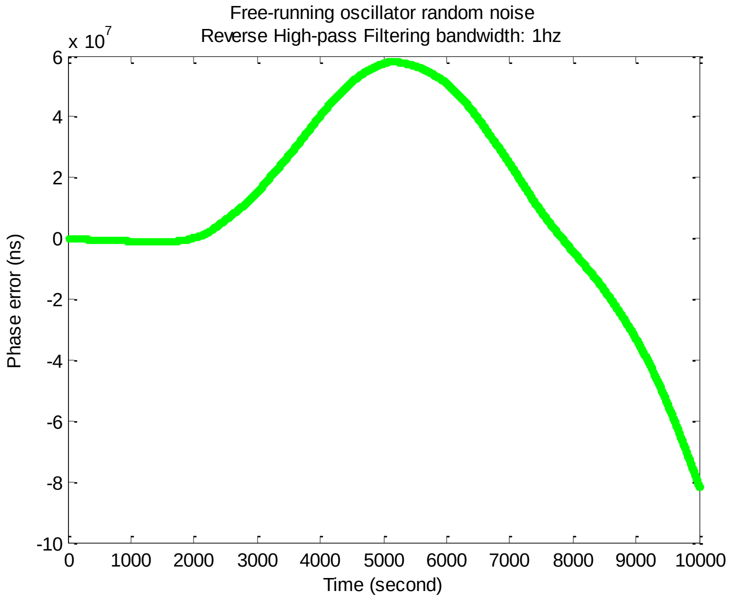
$$N = \frac{1}{1-H} \times Y$$

- The important factors of the low-pass filter model *H* are the filtering bandwidth and gain peaking. ITU-T G.813/G.8262 specify the filtering bandwidth to be 1~10Hz, and the gain peaking is 0.2dB.

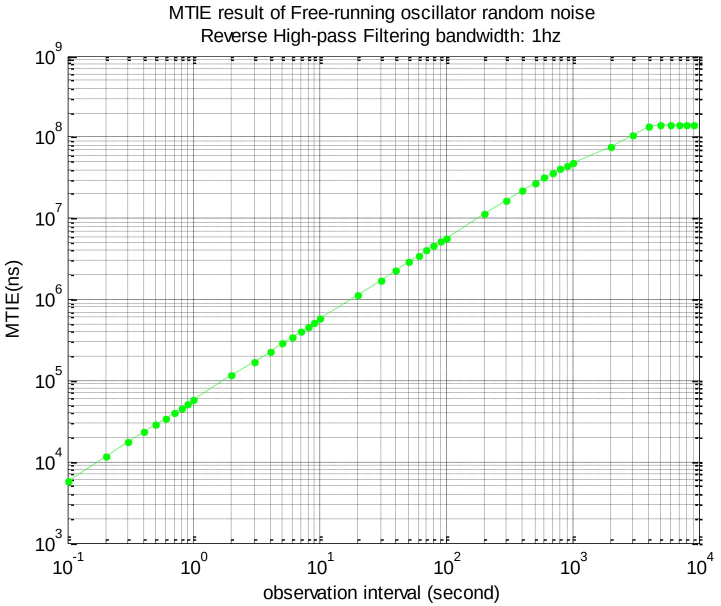
- So, the derivation of N considers two cases,
  - Case 1: filtering bandwidth 1Hz, gain peaking 0.2dB
  - Case 2: filtering bandwidth 10Hz, gain peaking 0.2dB

Clock noise model

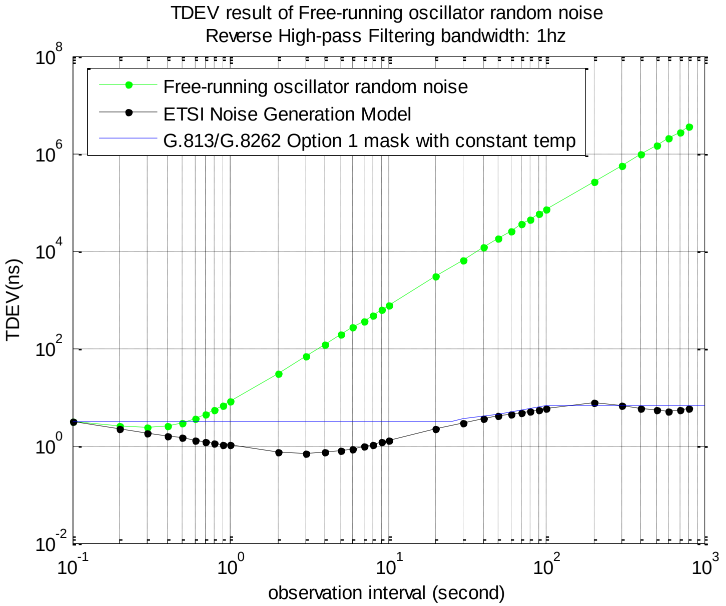
- Below figures are the simulation result of Case 1 (filtering bandwidth 1Hz, gain peaking 0.2dB)



Local clock noise, which can be assumed as the random noise of a local clock, mainly driven by a free-run oscillator



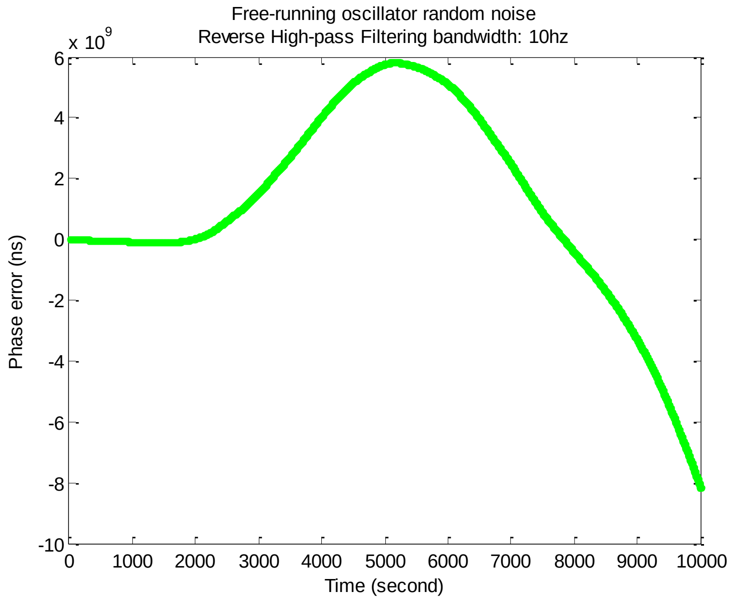
MTIE result

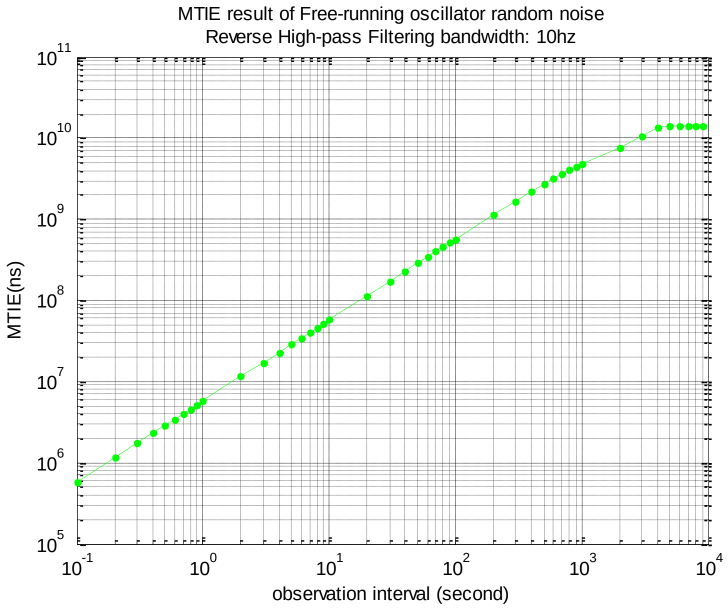


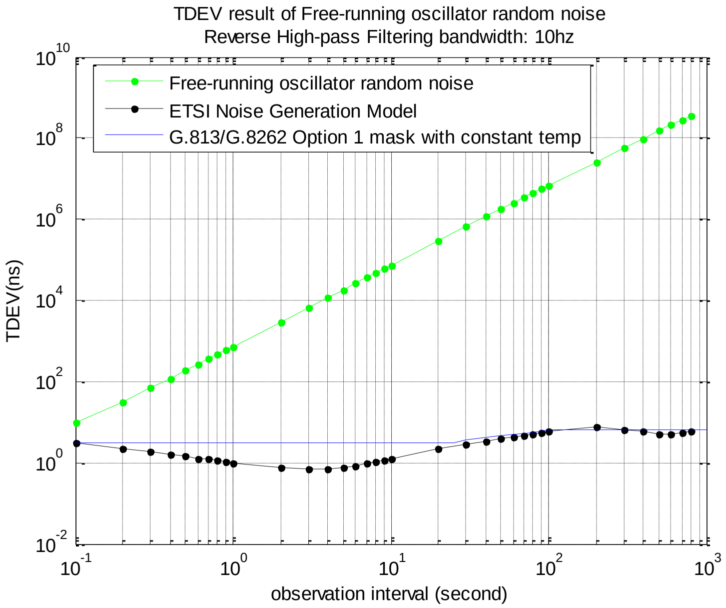
TDEV result

Clock noise model

- Below figures are the simulation result of Case 2 (filtering bandwidth 10Hz, gain peaking 0.2dB)







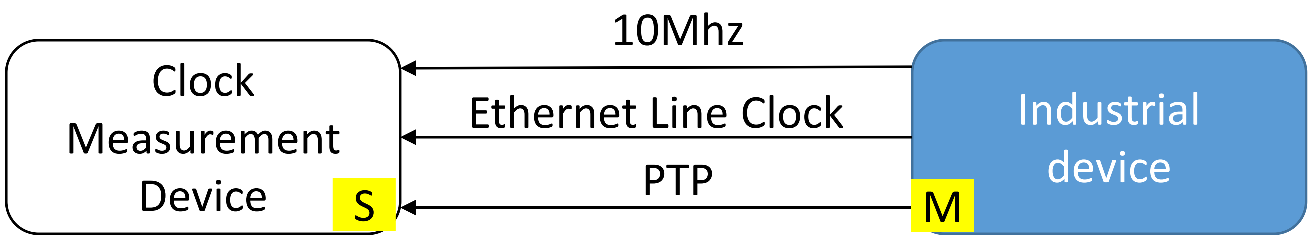
Local clock noise, which can be assumed as the random noise of a local clock, mainly driven by a free-run oscillator

MTIE result

TDEV result

Summary

- This presentation provides one method to get the random noise of local clock (a free-run oscillator), based on the ITU-T clock models.
    - However, it's still not quite sure, whether the result is consistent with the oscillators used by industrial devices. The ITU-T clock models assume telecom devices with TCXO, and the industrial devices may use XO.
- Another direct way that could be more consistent with the industrial devices is to test the local clock of a general industrial device.
    - There are several ways for test, e.g., through an external clock signal (e.g., 10Mhz), an Ethernet line clock from an Ethernet port, or PTP messages (e.g., t2 – t1, or t2 – t1 - meanLinkDelay).
    - Both of constant temperature and variable temperature can be tested.
    - It's better to test the output of a device instead of an oscillator. They could be different, especially for the variable temperature.



Thank you