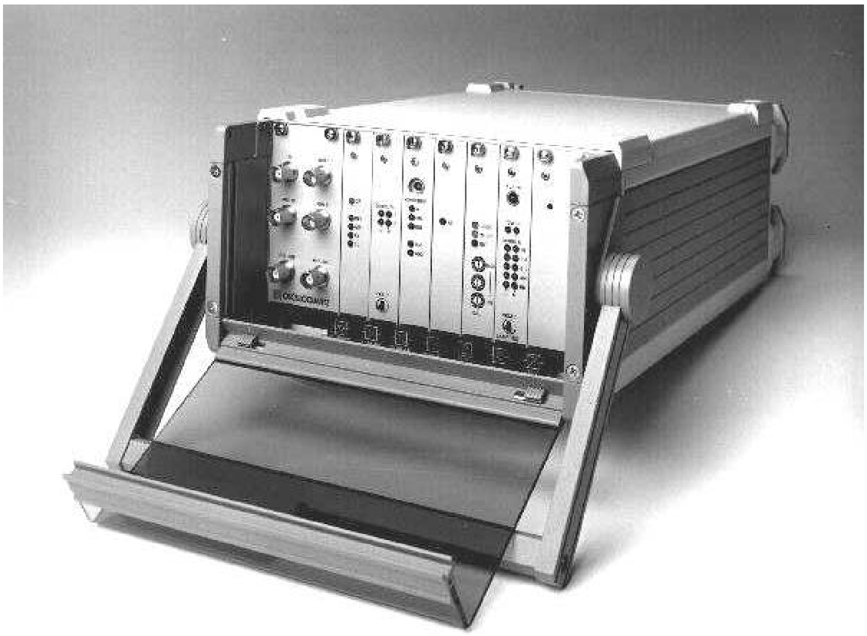
Application Note

Number 04/2000 Updated: 18/04/2000

Evaluating Measurement Data to Determine the Effect of Different Noise Sources Generated by Clock Signals



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1 Introduction

The OSA 5565 STS, Synchronisation Test Set, performs phase measurements (Time Interval Error) between an input signal and its internal high stability Rubidium reference. Measurement resolution is 100ps.

To facilitate the interpretation of the measurements, measurement data is processed by WinSTS, the STS software, and can be viewed using criteria specified by the industry standards - MTIE, TDEV, ADEV, MADEV and frequency error.

2 OSA 5565 Block Diagram

Figure 1 shows the block diagram for the OSA 5565 STS. All A-numbers refers to the module slot on the physical equipment.

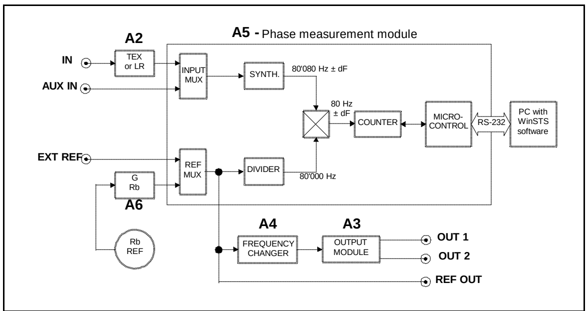

Figure 1: Block diagram of the OSA 5565 STS.

3 Formulas

Following chapter describes the different formulas calculated by the WinSTS software. The following constants are used in the formulas:

$x_i = x(i\tau_0)$	TIE for time $t = i\tau_0$
i	Measurement number $i = 1, 2, ..., N$
τ_0	Sampling time
$n\tau_0$	Observation period

MTIE (Maximum Time Interval Error)

$$MTIE(n\tau_0) = \max_{1 \le k \le N-n}\left[\max_{k \le i \le k+n} X(i) - \min_{k \le i \le k+n} X(i)\right]$$

ADEV (Allan DEViation)

$$\mathrm{ADEV}(n\tau_0) = \sqrt{\frac{1}{2n^2\tau_0^2(N-2n)}\sum_{i=1}^{N-2n}(x_{i+2n} - 2x_{i+n} + x_i)^2}$$

MADEV or MDEV (Modified Allan DEViation)

$$\mathrm{MADEV}(n\tau_0) = \sqrt{\frac{1}{2n^4\tau_0^2(N-3n+1)}\sum_{j=1}^{N-3n+1}\left[\sum_{i=j}^{n+j-1}(x_{i+2n} - 2x_{i+n} + x_i)^2\right]^2}$$

TDEV (Time DEViation)

$$\mathrm{TDEV}(n\tau_0) = \sqrt{\frac{1}{6n^2(N-3n+1)}\sum_{j=1}^{N-3n+1}\left[\sum_{i=j}^{n+j-1}(x_{i+2n} - 2x_{i+n} + x_i)^2\right]^2}$$

4 Measuring the equipment's noise

The aim of these measurements is to determine the effect of the different sources of noise generated by the equipment.

As seen in the illustrations below, the measurements on both the input and output interfaces are made against the same source - the equipment's internal high stability Rubidium.

4.1 Measuring the noise of the Phase Measurement Module

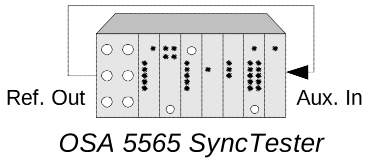

Figure 2: Measuring noise from the Phase Measurement module.

4.2 Measuring the noise of the Input Interface Unit

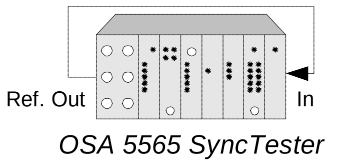

Figure 3: Measuring noise from the Input Interface Module.

4.3 Measuring the noise of the Output Interface Unit

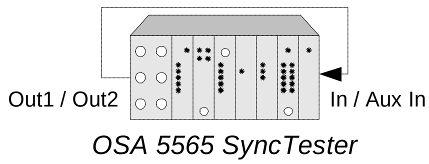

Figure 4: Measuring noise from the Output interface Module.

Note: If the output is a framed signal, e.g. HDB3, the appropriate input card must be fitted to the equipment, e.g. 2.048Mbit/s Input Interface Unit.

4.4 Evaluation

The results obtained from the measurements made above will determine the lower measurement limit of the OSA 5565 Synchronisation Test Set.

It is thus important to take this limit into account when making measurements to establish if the significance of these limits on the measurements.

5 Interpreting Measurement Data

The reason for making measurements with the OSA 5565 is to determine the quality of synchronisation references or to identify the factors that degrade a reference signal.

In an ideal case, comparison against masks defined by the industry standards and an understanding of the system noise are sufficient criteria for acceptance of the measurement results.

However, it is often the case that undesirable, measurable or pseudo-random affect the measurement and masks the normal behaviour of the sources or measured elements. It is therefore useful to separate the different factors contributing to this and to determine their cause.

The tables below show the relationship between the type of perturbation and its effect on the relevant parameter, MTIE or TDEV.

x (t)	**MTIE (τ)**
Initial phase offset $\mathbf{x_o}$	= 0
Initial frequency offset $\mathbf{y_o}$	= $\mathbf{y_o}$ x τ
Frequency ageing **D**	= **D** ($\mathbf{t_{max}}$ x τ **-** τ^2 / **2**)
Phase jump Δ**x**	= Δ**x** for all $\tau > t_0$
Sinusoidal Phase Modulation **A**sin (2πnt_0/**T**)	= **2** x **A** for τ > **T** / 2
White Phase Noise **WPM**	Depends on the distribution of the amplitude
Phase Flicker Noise **FPM**	
White frequency Noise **WFM**	
Freq. Flicker Noise **FFM**	
Freq. Random Walk **RFM**	

x (t)	**TDEV (τ)**
Initial phase offset $\mathbf{x_o}$	= **0**
Initial frequency offset $\mathbf{y_o}$	= **0**
Frequency ageing **D**	= (**D** / $\sqrt{}$**6**) x τ^2
Phase jump Δ**x**	See simulation attached
Sinusoidal Phase Modulation **A**sin (2πnt_0/**T**)	See simulation attached
White Phase Noise **WPM**	Proportional to $\tau^{-1/2}$
Phase Flicker Noise **FPM**	Proportional to τ^0
White frequency Noise **WFM**	Proportional to $\tau^{1/2}$
Frequency Flicker Noise **FFM**	Proportional to τ^1
Frequency Random Walk **RFM**	Proportional to $\tau^{3/2}$

x (t)	**ADEV (τ)**
Initial phase offset $\mathbf{x_o}$	= **0**
Initial frequency offset $\mathbf{y_o}$	= **0**
Frequency ageing **D**	= (**D** / $\sqrt{}$**2**) x τ
Phase jump Δ**x**	See simulation attached
Sinusoidal Phase Modulation **A**sin (2πnt_0/**T**)	See simulation attached
White Phase Noise **WPM**	Proportional to τ^{-1}
Phase Flicker Noise **FPM**	Proportional to τ^{-1}
White frequency Noise **WFM**	Proportional to $\tau^{-1/2}$
Frequency Flicker Noise **FFM**	Proportional to τ^0
Frequency Random Walk **RFM**	Proportional to $\tau^{1/2}$

x (t)	**MADEV (τ)**
Initial phase offset $\mathbf{x_o}$	= **0**
Initial frequency offset $\mathbf{y_o}$	= **0**
Frequency ageing **D**	= (**D** / $\sqrt{}$**2**) x τ
Phase jump Δ**x**	See simulation attached
Sinusoidal Phase Modulation **A**sin (2πnt_0/**T**)	See simulation attached
White Phase Noise **WPM**	Proportional to $\tau^{-3/2}$
Phase Flicker Noise **FPM**	Proportional to τ^{-1}
White frequency Noise **WFM**	Proportional to $\tau^{-1/2}$
Frequency Flicker Noise **FFM**	Proportional to τ^0
Frequency Random Walk **RFM**	Proportional to $\tau^{1/2}$

The graphs that follow represent the result of various simulations made from acquisitions of 2000 points.

The comparison of the simple cases shows the theoretical behaviour described in the above tables as well as the influence of the measurable events.

6 Predefined Templates

A set of predefined templates is attached to the WinSTS software. The Operating Manual of the OSA 5565 STS describes how these templates can be loaded and displayed on a screen, in order to compare them with measurement results. The last table gives a description of each template included in the WinSTS software.

The predefined templates for synchronisation equipment are derived from the latest ITU-T Recommendations:

- ITU-T Recommendation G.811 (05/96) for PRCs
- ITU-T Recommendation G.812 (12/98) for SSUs
- ITU-T Recommendation G.813 (08/96) for SECs
- Draft ITU-T Recommendation G.823 (11/98) for Network Limits on synchronisation interfaces. These Network Limits happen to be the same as those of ETS 300 462-3.

ITU-T Recommendation G.812 (12/98) specifies six types of Synchronisation Supply Units (SSU). The primary applications of these SSU types are the following:

SSU Type	*Primary Application*	
	Hierarchy	Which cases?
Type I	2048 kbit/s	Synchronisation chains as long as the synchronisation reference chain specified in ITU-T Rec. G.803
Type II	1544 kbit/s[3]	• Distribution hubs[1] • In cases where only one single input reference is available
Type III	1544 kbit/s[3]	End offices[1]
Type IV	1544 kbit/s[3]	Existing[2] networks (comment: the bandwith of this clock is close to the bandwith of a SEC)
Type V	1544[3] & 2048 kbit/s	Existing[2] transit nodes; same as Transit Node Clock (TNC) in ITU-T Rec. G.812 - 1988
Type VI	2048 kbit/s	Existing[2] local nodes; same as Local Node Clock (LNC) in ITU-T Rec. G.812 - 1988

Note 1: See Bellcore terminology.
Note 2: Prior to introduction of SDH.
Note 3: The 1’544kbit/s hierarchy includes the rates 1’544kbit/s, 6’312kbit/s and 44’736kbit/s.

For secondary applications of these SSU types, see section 2 of ITU-T Recommendation G.812 (12/98).

ITU-T Recommendation G.813 (08/96) specifies two types of SDH Equipment Slave Clocks called 'SEC Option 1' and 'SEC Option 2'. 'SEC Option 1' applies to SDH networks optimised for the 2’048kbit/s hierarchy. These networks allow synchronisation chains, which are as long as the synchronisation reference chain specified in ITU-T Recommendation G.803. 'SEC Option 2' applies to SDH networks optimised for the particular 1’544kbit/s hierarchy, which includes the rates 1’544kbit/s, 6’312kbit/s and 44’736kbit/s. The synchronisation reference chain for these networks is still under study at ITU.

The specifications contained in ITU-T Recommendations G.811, G.812 and G.813 are derived from other standards. The following table shows to which other standards they correspond:

ITU-T Rec.	Equip. Type	Other Standard	Equipment Type
G.811	PRC	ETS 300 462-6	Primary Reference Clock (PRC)
G.812	SSU Type I	ETS 300 462-4	Synchronisation Supply Unit (SSU)
	SSU Type II	Draft ANSI T1.101	Stratum 2 Clock
	SSU Type III		Stratum 3E Clock
	SSU Type IV		Stratum 3 Clock
	SSU Type V	ITU-T G.812 – 1988	Transit Node Clock (TNC)
	SSU Type VI		Local Node Clock (LNC)
G.813	SEC Option 1	ETS 300 462-5	SDH Equipment Slave Clock (SEC)
	SEC Option 2	Bellcore GR-253-CORE	SONET Minimum Clock (SMC)

Nº	Title	File name
1	Network limit for wander at PRC outputs expressed as MTIE	NETWORK LIMIT PRC ETS 300 462-3.mti
2	Network limit for wander at PRC outputs expressed as TDEV	NETWORK LIMIT PRC ETS 300 462-3.tdv
3	Network limit for wander at SSU outputs expressed as MTIE	NETWORK LIMIT SSU ETS 300 462-3.mti
4	Network limit for wander at SSU outputs expressed as TDEV	NETWORK LIMIT SSU ETS 300 462-3.tdv
5	Network limit for wander at SEC outputs expressed as MTIE	NETWORK LIMIT SEC ETS 300 462-3.mti
6	Network limit for wander at SEC outputs expressed as TDEV	NETWORK LIMIT SEC ETS 300 462-3.tdv
7	Network limit for wander at PDH distribution outputs expressed as MTIE	NETWORK LIMIT PDH ETS 300 462-3.mti
8	Network limit for wander at PDH distribution outputs expressed as TDEV	NETWORK LIMIT PDH ETS 300 462-3.tdv
9	Wander generation for a PRC expressed as MTIE	WANDER GENERATION PRC G811.mti
10	Wander generation for a PRC expressed as TDEV	WANDER GENERATION PRC G811.tdv
11	Wander generation for SSU Type I at constant temp. expressed as MTIE	WANDER GENERATION SSU I G812.mti
12	Wander generation for SSU Type I at variable temp. expressed as MTIE	WANDER GEN VAR TEMP SSU I G812.mti
13	Wander generation for SSU Type I at constant temp. expressed as TDEV	WANDER GENERATION SSU I G812.tdv
14	Wander generation for SSU Types II & III at constant temp. expressed as MTIE	WANDER GENERATION SSU II&III G812.mti
15	Wander generation for SSU Types II & III at constant temp. expressed as TDEV	WANDER GENERATION SSU II&III G812.tdv
16	Wander generation for SSU Type IV at constant temp. expressed as MTIE	WANDER GENERATION SSU IV G812.mti
17	Wander generation for SSU Type IV at constant temp. expressed as TDEV	WANDER GENERATION SSU IV G812.tdv
18	Wander generation for SSU Types V & VI at constant temp. expressed as MTIE	WANDER GENERATION SSU V&VI G812.mti
19	Noise transfer for SSU Type I expressed as TDEV	NOISE TRANSFER SSU I G812.tdv
20	Noise transfer for SSU Types II & III expressed as TDEV	NOISE TRANSFER SSU II&III G812.tdv
21	Noise transfer for SSU Types IV expressed as TDEV	NOISE TRANSFER SSU IV G812.tdv
22	Short-term phase transient response for SSU Type I expressed as MTIE	SHORT TRANSIENT SSU I G812.mti
23	Short-term phase transient response for SSU Types II & III expressed as MTIE	SHORT TRANSIENT SSU II&III G812.mti
24	Short-term phase transient response for SSU Type IV expressed as MTIE	SHORT TRANSIENT SSU IV G812.mti
25	Short-term phase transient response for SSU Types V&VI expressed as MTIE	SHORT TRANSIENT SSU V&VI G812.mti
26	Phase discontinuity for SSU Type I expressed as MTIE	PHASE DISCONTINUITY SSU I G812.mti
27	Phase discontinuity for SSU Types II & III expressed as MTIE	PHASE DISCONTINUITY SSU II&III G812.mti
28	Phase discontinuity for SSU Type IV expressed as MTIE	PHASE DISCONTINUITY SSU IV G812.mti
29	Phase discontinuity for SSU Types V & VI expressed as MTIE	PHASE DISCONTINUITY SSU V&VI G812.mti
30	Wander generation for SEC Option 1 at constant temp. expressed as MTIE	WANDER GENERATION SEC 1 G813.mti
31	Wander generation for SEC Option 1 at variable temp. expressed as MTIE	WANDER GEN VAR TEMP SEC 1 G813.mti
32	Wander generation for SEC Option 1 at constant temp. expressed as TDEV	WANDER GENERATION SEC 1 G813.tdv
33	Wander generation for SEC Option 2 at constant temp. expressed as MTIE	WANDER GENERATION SEC 2 G813.mti
34	Wander generation for SEC Option 2 at constant temp. expressed as TDEV	WANDER GENERATION SEC 2 G813.tdv
35	Noise transfer for SEC Option 2 expressed as TDEV	NOISE TRANSFER SEC 2 G813.tdv
36	Short-term phase transient response for SEC Option 2 expressed as MTIE	SHORT TRANSIENT SEC 2 G813.mti
37	Long-term phase transient response (holdover) for SEC Option 2 expressed as MTIE	HOLDOVER TRANSIENT SEC 2 G813.mti