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	Guide of Phase Jitter Measurement Method for Quartz Crystal Oscillators and SAW Oscillators	2006 - 05, E1
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Guide of Phase Jitter Measurement Method for Quartz Crystal Oscillators and SAW Oscillators

Introduction This standard applies to the phase jitter measurement of crystal oscillators and SAW oscillators used for electronic devices.

1. Scope

This standard applies to crystal oscillators and SAW oscillators, as well as modules that have a multiplication function or a division function based on these oscillators. The type of phase jitters applied to these oscillators shall be the "data-independent" RMS jitter. Hereinafter, these oscillators and modules are referred to as "oscillators" for simplicity.

Remarks The international standards corresponding to this standard are not provided.

2. Normative reference

The standard listed below is cited in this standard, and thus forms a part of provisions of this standard. These normative references apply the latest version (including the supplements).

IEC 60679-1 Ed. 2 Amd. 2: Quartz crystal controlled oscillators of assessed quality - Part 1: Generic specification

3. Priority

The specification is fixed by the priority shown below when any discrepancy arises for some reason.

- Individual standards
- General rules according to types
- General rules according to items
- Other international codes and standards (for example, IEC) as cited

The same priority also applies to equivalent domestic standards.

4. Terms

The definition of terms applied to the phase jitter is shown in **Commentary**.

5. General matters

The units, graphical symbols, and letter symbols are based on **IEC 60679-1 Ed. 2 Amd. 2**.

6. Measurement method

The measurement method applied to oscillators is based on the following.

6.1 Frequency range and measurement method

The measurement range shall be 10MHz to 700MHz. As the measurement method, the phase noise measurement equipment (system) or the specially designed phase jitter measurement equipment shall be used.

6.2 Method of obtaining from phase noise measurement values (Recommended)

The measurement method for the amount of phase jitter using the phase noise measurement is based on the following.

a) Measuring device and system

The measurement device and system shall be the phase noise measurement equipment or the phase noise measurement system.

b) Measurement items

The measurement items shall be the RMS jitter.

c) Range of detuned frequency

The range of detuned frequency shall be determined by contracts between customers and supplier sides after discussing there between. The formula of calculating the RMS jitter from a phase noise is based on "Calculation Method for the Amount of Phase Jitter" shown in **Annex A**.

d) Phase noise measurement method

As the phase noise measurement method, an orthogonal phase detection method (referred to also as an orthogonal comparison method or a PLL method) shall be used, or the measurement equipment having built-in electronic circuits for canceling a noise in the measurement system (for example, circuits adopting a cross correlation method) shall be used.

6.3 Method of using specially designed measurement equipment

The specification of the method using the specially designed measurement equipment is based on the following.

a) Measurement device and system

The measurement device and system shall be the specially designed SONET/SDH measurement equipment by using a time interval analyzer.

b) Measurement items

The measurement items shall be the RMS jitter and the period jitter or

periodic jitter.

c) Measurement times

The measurement times shall be determined by contracts between customers and supplier sides after discussing there between. The target measurement times shall be 20,000 times or more.

Remarks Attention is needed because this device may not meet the requirements of oscillators from the following reasons:

1. The measurable range of the measurement equipment may not meet the frequency of oscillators to be measured.
2. The output voltage of oscillators is lower as compared with this device. For this reason, an amplifier is required, and the necessity of evaluating the phase jitter of the amplifier arises.
3. The realization of square waves, such as CMOS, LVDS, and LVPECL, is difficult because harmonics components decrease in the frequency bands exceeding 300MHz. For this reason, the signal waveforms become sine waves, clipped-sine waves and the like which are difficult to be analyzed by the specially designed SONET/SDH measurement equipment, and thus a decrease in measurement accuracy is concerned.

6.4 Block diagram of measurement

A representative block diagram is shown in Figure 1. A practical block diagram is utilized as modified forms of Figure 1.

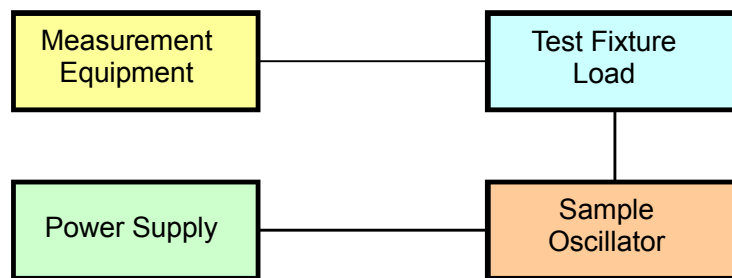


Figure 1 Representative block diagram of measurement system

6.5 Input-output impedance of measurement system

The load impedance of oscillators widely ranges from 5ohm to 100Mohm. The parts to be applied are the three types as shown in the following. However, since numerous demands are made by customers, the values of this load impedance are in infinite variety.

- a) Only capacitor
- b) Only resistive element
- c) Combined use of capacitor and resistive element

Here, since the measurement system is unified into 50ohm, the input-output impedance of measurement systems shall be 50ohm. For this reason, the load impedance of oscillators also shall be 50ohm.

The oscillation output voltage changes depending on the load impedance of oscillators. For this reason, the thermal noise of load circuits also changes.

As a result, since the amount of phase jitter changes, a recommendation is presented for suppliers and customers, when adopting any load impedance other than 50ohm, to conduct a detailed study and examination, and to determine by contracts therebetween.

6.6 Measurement equipment

The specification required for the measurement equipment is described in the following without any necessity of persisting to this specification. To adopt the measurement equipment sufficiently satisfying the requirements of oscillators is important.

a) Jitter floor

The jitter floor shall take values of 0.05ps or less as the random jitter, or values smaller by one digit as compared with the phase jitter demanded for the oscillators.

b) Frequency range

The frequency range shall be 10MHz to 700MHz. Plural measurement equipments may be used according to each frequency band.

c) Output waveforms

The output waveforms shall be CMOS, LVDS, LVPECL, clipped-sine waves, sine waves, etc.

Remarks CMOS, LVDS, and LVPECL originally refer to the type of devices, and not a waveform per se. However, they are used also as the terms showing the waveforms, and therefore are described as the type of output waveforms in this paper.

d) Output voltage

The output voltage shall be 500mV or more.

6.7 Measurement implements

The specification demanded for measurement implements is shown in the following.

- a) Connection between oscillators to be measured and measurement implements

The application of sockets, connectors, screws, clips, and the like may be allowed. In addition, the oscillators to be measured and the measurement implements shall be ensured to be mechanically and electrically connectable.

- b) Compatibilization of oscillators to be measured and measurement implements

The oscillators to be measured and the measurement implements shall be able to be earthed.

- c) Although the load impedance may not be built-in, a recommendation is presented to use measurement implements having the load impedance built therein in order to reduce influences on the phase jitter of the oscillators to be measured from a thermal noise or the like from the load impedance.

6.8 Cable, tools and instruments, etc.

As for a cable, the double shield type of 50ohm system shall be used. The cable shall be shortest as much as possible. As connectors, the 50ohm system shall be used. A recommendation is presented to use SMA or N-type connectors.

7. Measurement and measurement environment

7.1 Preparation before measurement

Attention is paid to the following matters.

- a) The entire measurement system and the oscillators to be measured shall be installed in a measurement chamber before two hours or more.
- b) The measurement equipment shall be caused to operate for 2 hours or more.
- c) The frequency stability of clock signals in the measurement equipment shall be verified to be smaller than, or equivalent to, the frequency stability of the oscillators to be measured.
- d) The power supply voltage of the oscillators to be measured and the measurement equipment shall be verified to be set to the AC voltage and the DC voltage as demanded.
- e) Restrictions shall be provided for operation of surrounding electronic devices so as not to produce an electronic noise from the surrounding.

7.2 Points to consider and note at the time of measurement

No vibration of the measurement system shall be caused. No movement shall be caused. No shifting of the cable position shall be made.

7.3 Treatment after measurement, etc.

No disassembling of the measurement system is desirable. The periodical inspection and calibration of the measurement equipment shall be ensured.

8. Measurement

8.1 Reference temperature

The reference temperature shall be $+25 \pm 5$.

8.2 Measurement of temperature characteristics

Only the oscillator to be measured shall be caused to immobilize in the precisely variable temperature bath as appropriately selected, and the temperature characteristics shall be measured. No vibration shall be caused.

8.3 Measurement under vibration

Only the oscillator to be measured shall be fixed to the shaker as appropriately selected, and caused to vibrate. No vibration of the measurement equipment shall be caused.

8.4 Measurement at the time of impact

Only the oscillator to be measured shall be fixed to the impact machine as appropriately selected to apply impact thereto. Moreover, no shock wave or no vibration accompanied with the impact shall be provided for the measurement equipment.

In addition, this testing is not realistic because the impact period of time is shorter than the measurement period of time. If this testing is performed, a recommendation is presented for suppliers and customers to conduct a detailed study and examination, and to determine by contracts therebetween.

8.5 Measurement in accelerated ageing

Only the oscillator to be measured shall be set to the temperature and time based on the specification in the temperature bath as appropriately selected, and then caused to immobilize, and thus the accelerated ageing shall be measured.

9. Other points to note

A consideration shall be taken so as to obtain the measurement results understandable to suppliers and customers by eliminating any possibility that an electronic noise may be involved in the measurement system from the supply source line through paying attention also to the phase jitter of the devices applied to the measurement system, or to be applied around the system.

10. Standard

As for the amount of phase jitter of crystal oscillators and SAW oscillators, as well as modules that have a multiplication function or a division function based on these oscillators, customers and suppliers shall conduct a detailed study and examination, and determine by contracts therebetween.

Annex A (Standard)

Calculation Method for the Amount of Phase Jitter

Introduction

This standard shows the method of calculating the amount of phase jitter from phase noise measurement results.

A1. Explanation

When the amount of phase jitter is calculated from the phase noise measurement results, the RMS jitter can be obtained. The details are described in the following.

If a spectrum analyzer or a phase noise measurement system is used, the phase jitter can be analyzed to have what frequency components, which can be used for the cause analysis of the phase jitter. According to the measurement of the phase jitter by the phase noise measurement system, the ultra-low amount of phase jitter, which cannot be measured by other jitter measurement methods, can be measured, and thus the phase noise measurement system is suitable for evaluating highly stable devices such as crystal oscillators. Relative to the signals of crystal oscillators, various types of signal waveforms such as sine waves and square waves are demanded by customers. Among them, as for the sine wave signals, the application of phase noise measurement system is theoretical and appropriate. However, as for the square wave signals, although error-increasing factors are involved, since any other method capable of firmly measuring the ultra-low amount of phase jitter is not yet found at present, the phase noise measurement system is actually obliged to be applied even to the square wave signals.

In general, when the measurement results of a SSB phase noise of crystal oscillators are viewed, the offset frequency in the horizontal axis is described such as 10[Hz] to 1[MHz], 1[Hz] to 1[MHz], and 1[Hz] to 10[MHz] in many cases. In particular, for the offset frequency of 10[kHz] or more as the floor level, the offset frequency is described as 1[MHz] or 10[MHz]. Such the offset frequency is obtained because filters are provided in the measurement equipment.

On the other hand, as for the phase jitter, since such the filters are not required, the measurement values can be obtained regardless of the offset frequency.

Therefore, no complete coincidence can be maintained to be provided for the phase noise measurement values and the phase jitter measurement values. However, in the case of oscillators having the ultra-low amount of phase jitter such as the crystal oscillators, the phase noise measurement values and the phase jitter are required to be correlated, and therefore the phase noise and the phase jitter are utilized for convenience.

A2. Relations between phase noise and phase jitter

When phase modulations are demodulated by a phase detector (converting phase fluctuations into voltage fluctuations), the relationship between phase and voltage can be expressed by the formula (1), wherein K_ϕ is a constant, and the unit of K_ϕ is [V/rad].

$$\Delta V_{out} = K_\phi \cdot \Delta\phi \quad \dots\dots\dots(1)$$

When the converted phase fluctuations are measured by a spectrum analyzer, the relationship can be expressed by the formula (2),

$$\Delta V_{rms}(f) = K_\phi \cdot \Delta\phi_{rms}(f) [V] \quad \dots\dots\dots(2)$$

wherein, if $S_{v_{rms}}(f)$ is defined as the spectral density function of the voltage fluctuations (output fluctuations of the phase detector) as measured, the spectral density function of the phase fluctuations can be expressed by the formula (3).

$$\begin{aligned} S_\phi(f) &= \frac{(\Delta\phi_{rms}(f))^2}{B} \\ &= \frac{(\Delta V_{rms}(f))^2}{K\phi^2 \cdot B} \\ &= \frac{S_{v_{rms}}(f)}{K\phi^2} \left[\frac{rad^2}{Hz} \right] \dots\dots\dots(3) \end{aligned}$$

When the results are converted into the SSB phase noise as shown below, the SSB phase noise can be expressed by the formula (4),

$$L(f) = \frac{S_\phi(f)}{2} \quad \dots\dots\dots(4)$$

wherein $S_\phi(f)$ is a dB value relative to 1 radian, and also the power spectral density function of the phase fluctuations, and L (f) is the Single Sideband(SSB) phase noise.

A total phase deviation in the designated band, namely, the phase jitter, can be expressed by the formulae (5) and (6).

$$\Phi = \sqrt{\int_A^B S_{\phi}(f) \cdot df} \quad [\text{rad}] \dots\dots\dots (5)$$

$$\Phi = \sqrt{\int_A^B 2 \cdot L(f) \cdot df} \quad [\text{rad}] \dots\dots\dots (6)$$

Therefore, the shaded parts (area of SSB phase noise) shown in Figure 2 can be referred to as the phase jitter. This area corresponds to the RMS jitter. Here, if the offset frequency range is different, the phase jitter calculation value becomes different. Since the fact is a shortcoming of this method, attention is needed to be paid when calculating the phase jitter from the SSB phase noise.

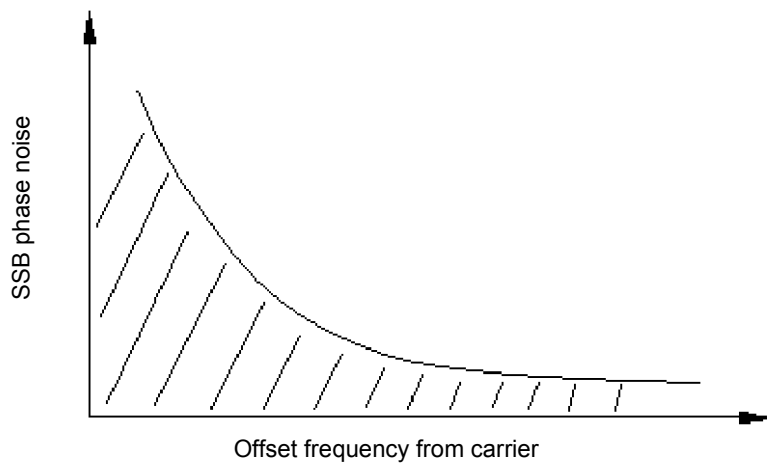


Figure 2 Concept diagram of SSB phase noise

Commentary

1. History of establishment and points to note

The study of phase jitter measurement methods has been conducted in accordance with the agreement during the IEC TC49 Berlin international meeting in 2001. In this meeting, the decision has been made for Japan to assume the responsibilities of this study. Then, the technical committee of QIAJ has proceeded with this study. This study has been substantially conducted during the years of 2002 to 2005, and can be referred to as the first stage without any exaggeration. The study is subsequently continued at present as positioned to be the second stage.

The phase jitter has become one of essential measurement items by digitization of electronic devices. However, some ambiguity is still left in the phase jitter theoretically. Since any measurement method as the standard is not proposed, suppliers and customers may be mutually exposed to a risk to cause enormous economic losses.

To avoid this risk, this paper provides the standard established, based on the study results during the first stage, for each company of QIAJ members to avoid any anxiety as to the measurement of the phase jitter, and for the purpose of guiding without any mistakes.

In a part of this paper, unsolved issues are still remained. However, since this part is designated to be solved during the second stage, if any doubts are created, a sincere request is addressed for suppliers and customers to mutually consult so as to solve the issues.

Next, in this paper, a recommendation is presented to make the RMS jitter as a measurement object. This recommendation is submitted because, as the object to be measured, the oscillators resulting in the ultra-low amount of jitter are targeted.

The oscillators are analogue-type electronic devices. As for the signals, the sine wave output of the oscillators is more favorable than the sine wave output of electronic systems. Moreover, the output is utilized as the reference clock of the measurement equipment. Therefore, such a case is frequently experienced as showing the amount of phase jitter smaller than the amount of phase jitter of the

measurement equipment. Accordingly, such a case may be experienced that the measured amount of phase jitter is not from the oscillators, and shows the amount of phase jitter on the side of the measurement equipment, or of the measurement system. Therefore, when adopting the amount of other phase jitters as the measurement items, a recommendation is presented to select the measurement equipment and the measurement system sufficiently capable of being verified and confirmed, and to determine by contracts between suppliers and customers. Moreover, when the phase noise method is used, the random jitter values are required to be discussed after defining the jitter frequency bands from start to end of integrating the phase noise.

If any doubts are created as to the measurement values, the study of applying [Allan Variance] which can be theoretically described is sincerely asked [1].

2. Theoretical positioning of phase jitter

The frequency stability has been compiled into a single work, for the present, by “Special Issue on Frequency Stability” by IEEE in 1966 [2]. Then, the definition is applied to atomic oscillators, crystal oscillators, as well as electronic systems for telecommunication, information, audio-visual, and the like.

The conventional crystal oscillators and electronic systems have analogue systems with exception of a part, and the signal waveforms are sine waves. Therefore, the short term frequency stability as one field of the frequency stability is measured as the phase noise or Allan Variance. Recently, digitization of electronic systems is progressing. Under such the circumstance, the short term frequency stability has been measured as the phase jitter.

On the other hand, the oscillators are analogue-type electronic devices. For the oscillators, the signals having square waves or waveforms similar thereto are demanded by users for facilitating to be assembled into the electronic systems. Naturally, for the short term frequency stability, the measurement as the phase jitter is frequently demanded by users.

3. Definition of terms

According to this standard, the terms applied to the phase jitter are defined and described.

The “phase jitter” of oscillators means an “electronic noise” of signal waveforms in terms of time. On the other hand, the phase jitter is defined as a “jitter” in which the frequency of signal deflection exceeds 10[Hz], and as a “wander” in which the frequency is 10[Hz] or less.

The “wander” of oscillators is difficult to be observed. The “wander” is a phenomenon which is confirmed in electronic parts such as optical cables susceptible to expansion and contraction even by a small amount of temperature changes. Therefore, the “wander” is not generally discussed in the oscillators. In this paper also, the phase jitter is targeted only to the “jitter”.

As for signals, an ideal one cycle (t) is inversely proportional to a frequency (f). More specifically, the relation is expressed by the formula (1).

$$t = \frac{1}{f} \dots\dots\dots (1)$$

Actually, the cycle is varied by receiving various influences. This phenomenon is the phase jitter, and can be confirmed by thickening of edges of waveforms when using oscilloscopes or the like. As the method of measuring and evaluating such the phase jitter, statistical measurement techniques are utilized. This phenomenon is shown in Figure 3. The numerical values in Figure 3 are treated as a symbol. The position of 0.5 of signal waveforms is defined as a reference point in the vertical axis, and the edges of the reference point are defined to be not varied. When attention is paid to the edges after one cycle, every time when the signals repeatedly move on the screen of CRT in the lateral direction, the edges after one cycle are not reproduced. Then, plural edges have become to exist. This phenomenon is induced when repeatedly measuring the signals, and referred to as the phase jitter.

This phase jitter is treated as a normal distribution. Then, when analyzed, the phase jitter can be divided into several types of properties. More specifically, the phase jitter is classified in several types. In this paper, the phase jitter is classified in the seven types as described below. In the following, these properties and the cause systems are made clear.

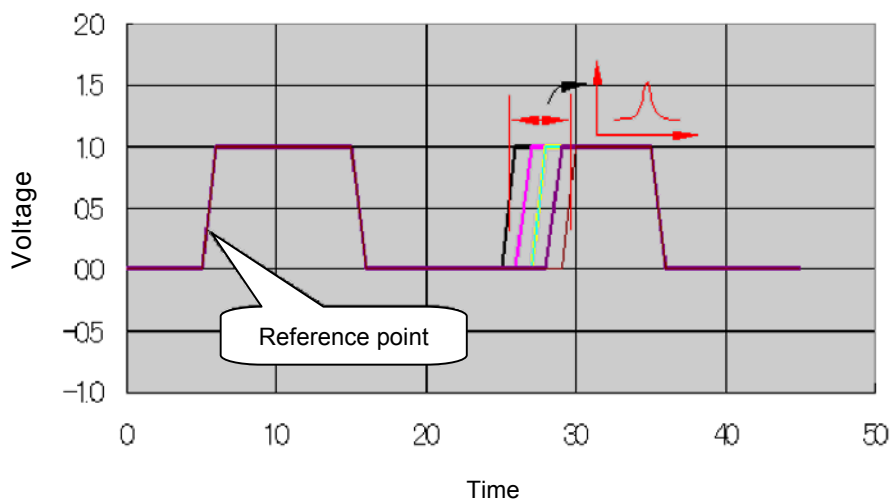


Figure 3 Voltage vs. time

3.1 RMS jitter

The RMS jitter is the phase jitter which comes to have the normal distribution shown in Figure 4. The RMS jitter is a standard deviation obtained based on statistical treatments, and defined as a 1σ portion.

From statistics, any measurement data is meant to exist in 1σ at a probability of 68.26%. Therefore, when the measurement times are 10,000 times, approximately 6,826 pieces of the measurement data are considered to be contained. On the contrary, 31.74% (3174 pieces) of the measurement data is indicated to be outside the plus and minus sides of 1σ . If the data outside the definition is considered to be errors, 31.74% can be considered to be the error rate.

3.2 Peak to peak jitter

The peak to peak jitter is the phase jitter which comes to have the normal distribution shown in Figure 4. The amount of phase jitter of one cycle is totalized, and statistically treated on the base point of the reference point of phase jitter shown in Figure 3. In this case, the amount of phase jitter is assumed to provide the normal distribution.

The difference between the maximum value and the minimum value (namely, change width) is referred to as the peak to peak jitter, or the cycle to cycle jitter. Since the jitter values become larger as the measurement times are increased, the jitter becomes also the total jitter as described later. This term comes on

when negotiating specifications between customers and oscillator makers.

Remarks Since the peak to peak jitter or the RMS jitter indicates the amount of phase jitter in the measurement times thereof, the jitter indicates operating conditions of measurement samples in a short period of time. Moreover, the jitter has values effective only to an ideal normal distribution (Gaussian distributions), and the effectiveness can be maintained to be low when considered for the cases of non-Gaussian distributions having distorted distributions such as binomial distributions and chi-square distributions. Accordingly, when applying the peak to peak jitter or the RMS jitter, the measurement times are required to be clearly defined by contracts between customers and supplier sides.

3.3 Random jitter

The random jitter is shown in Figure 5. The random jitter represents unpredictable phase jitter components.

The random jitter naturally and inductively occurs as influenced by the characteristics, thermal noise, and the like originally involved in the measurement equipment per se or oscillators. Furthermore, the random jitter has characteristics that the distribution width of measurement values becomes larger (namely, boundless characteristics) as the observation period of time becomes longer. Therefore, the distribution chart can be considered as an ideal normal distribution. Moreover, the random jitter is determined as a standard deviation based on the distribution chart obtained by the measurement of phase jitter. Accordingly, in the case of oscillators, the random jitter may become the amount of jitter equivalent to the RMS jitter. Moreover, since the random jitter becomes the amount of jitter of the measurement equipment per se, the random jitter is one of the measures for judging applicability to measuring the phase jitter of oscillators.

3.4 Deterministic jitter

The deterministic jitter occurs by various factors of regularity (circuit designs, electromagnetic induction, or induced from external environment), and has characteristics that the change width of distribution has a boundary, and thus can be expressed by the parts sandwiched between right and left random jitters. On

the other hand, the components forming the deterministic jitter include the period jitter or periodic jitter and the data-dependent jitter.

3.5 Period jitter or periodic jitter

While the RMS jitter represents variations in one cycle, the period jitter or periodic jitter shows variations of timings of multiple cycles consecutively provided such as two cycles and three cycles. The period jitter or periodic jitter can be determined by grasping the relationship with the RMS jitter between the multiple cycles and each cycle, and thus grasping whether or not periodic irregularities appear. As for the periodic components of this jitter, such components are considered as an electronic noise caused by the power supply, and cross talk from electronic parts around oscillators to be measured, and further from cores in the vicinity in the case of IC.

If the FFT (Fast Fourier Transform) can be executed, the frequency as the cause clearly appears as a spectrum. Although this jitter is naturally required to be considered for the oscillators, the jitter is difficult to be detected by using measurement equipments in general.

3.6 Data-dependent jitter

The data-dependent jitter is considered to be jitter components due to duty cycle distortion and inter symbol interference, and is negligible for oscillators.

3.7 Total jitter

The total jitter is defined as the jitter obtained by totalizing all of the jitters.

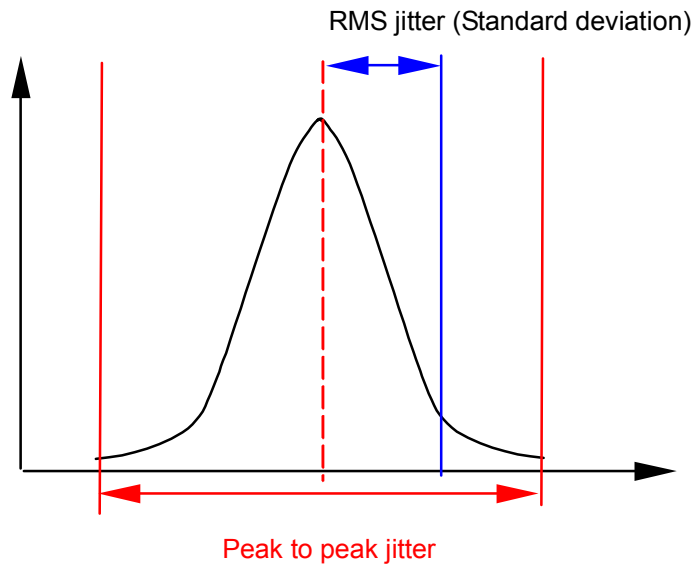


Figure 4 Explanatory diagram of the amount of jitter applied to RMS jitter

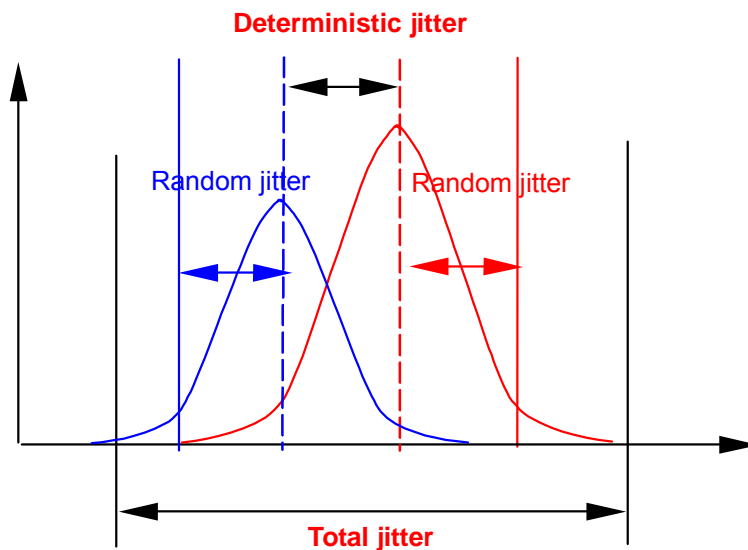


Figure 5 Explanatory diagram of random jitter, deterministic jitter, and total jitter

4. Points to consider for measurement

4.1 Measurement equipment

For the oscillators, the demands in infinite variety are provided by customers. The output waveforms are not limited to square waves. The demands for output voltage as small as not applicable to the measurement equipment also may be provided.

Since the oscillators have a ultra-low noise, such a case may be experienced that the amount of jitter of the measurement equipment per se is detected. Therefore, for the amount of jitter of the measurement equipment per se, the measurement equipment shall have the jitter floor smaller by one digit as compared with the amount of jitter of assumed oscillators. Moreover, the frequency range and the output waveforms are demanded to be applicable not only to square waves but also to sine waves.

Since measurement equipments in general are provided with the specification of a degree applicable to digital electronic systems, a sufficient study is required for adopting the measurement equipment for oscillator purpose.

- a) In the case of digital oscilloscopes, no appropriate measurement equipment for such the oscillator purpose is found.
- b) In the case of applying digital oscilloscopes to the phase jitter measurement, a recommendation is presented to select the measurement equipment and the measurement system capable of being sufficiently verified and confirmed, and to determine by contracts between suppliers and customers.
- c) In the case of specially designed measurement equipments to which a time interval analyzer is applied, in a part of measurement equipments, the type having such the shortcomings exists that the random jitter of jitter floor is equivalent to or larger as compared with oscillators, that the application of sine waves is difficult, that the low frequency cannot be applied to the range of such the oscillators, and that the output voltage is low and an amplifier is required. Therefore, a sufficient consideration is required for selecting the type of specially designed measurement equipments.
- d) The phase jitter may be calculated from phase noise measurement values by using the phase noise measurement equipment or the measurement system. In this case, the detuned frequency shall be determined by contracts between suppliers and customers. When the detuned frequency becomes outside the range of the phase noise measurement equipment or the measurement system, in particular, when the upper limit of the detuned frequency becomes a floor level, a consideration shall be taken not to produce a misunderstanding between customers and suppliers by defining that the voltage of floor level is flat according to contracts therebetween.

Within the range investigated during the first stage, no devices satisfying the requirements are found among sampling oscilloscopes and specially designed

measurement equipments. However, since such information is obtained that a part of specially designed measurement equipments satisfying the requirements has been put on the market, the specially designed measurement equipment is taken in the standard.

4.2 Factors of measurement errors

As for the oscillators, the factors of phase jitter measurement errors are shown in the following.

a) Power supply

The power supply is required for driving the oscillators. If unstable power supply is used, the unstable power supply is observed as converted into the jitter, and therefore the use of power supply having a sufficiently low noise is desirable. Since losses are produced for the wiring cable between power supply terminals and oscillators or amplifiers, and contact resistance is produced, the amount of phase jitter may be increased from this part.

b) Test fixer & load

The load is formed of resistors and fixed capacitors. Since the resistors exist, generation of electronic noise cannot be avoided. The possibility of playing a role of collecting the electronic noise as an antenna may be exemplified.

c) Amplifier (When using amplifier at the time of measurement)

The amplifier is formed of electronic parts including active elements and resistors. Therefore, generation of electronic noise cannot be avoided.

d) Cable

The cable includes losses therein, and therefore is an electronic noise generation source. Since the reflectance changes as the impedance changes through the change of length caused by temperature characteristics, the change may be misread as the wander. An electronic noise due to contact change of connectors may be provided. The possibility of playing a role of collecting the electronic noise as an antenna may be exemplified.

e) Input-output impedance of measurement system

The load impedance of oscillators widely ranges from 5ohm to 100Mohm. The parts used for the load impedance include three types; only capacitor, only resistance element, and combined use of capacitor and resistance element. In the case of only capacitor, phase jitter measurement values can be neglected. In the case of only resistance element, and combined use of capacitor and resistance element, attention is needed because the phase jitter measurement values can not be

neglected by the thermal noise from the resistance element.

f) Measurement of phase jitter for frequency exceeding 1GHz

In general, the waveforms of signals (including demodulated signals) exceeding 1GHz are modified sine waves. Therefore, attention is needed because the amount of phase jitter, which suppliers and customers are intended, may be difficult to be obtained by sampling oscilloscopes or specially designed measurement equipments.

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ITU-T: International Telecommunications Union - Telecommunications Standards Sector. This is the alternate acronym for ITU-TSS.

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CCIT-T: Comite Consultatif International Telegraphique et Telephonique.

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